Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 135

Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), Transportation 2000, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

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The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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Daniel Boyle, President of Dan Boyle & Associates, Inc., was the principal investigator with overall responsibility for the project and the primary author of the blocking and rostering chapters. John Pappas was the primary author for the chapters on schedule writing and rail scheduling. Phillip Boyle wrote the runcutting chapter and authored several of the advanced topic discussions. All team members freely edited each other's work throughout the project; Bonnie Nelson of Nelson/Nygaard did the final edit. Howard Benn served as senior advisor and was the final arbiter for technical disputes among the team. Mr. Benn also contributed the sections on overtime optimization and rail terminal layout.

Daniel Boyle, John Pappas, Phillip Boyle, and David Sharfarz (Nelson/Nygaard Consulting Associates) conducted the background case studies. David Jorns of Nelson/Nygaard designed and produced the final document for TCRP.

Dan Boyle & Associates, Inc., is grateful to all the transit agencies who responded to the lengthy survey on transit scheduling. The team especially thanks the schedulers and others at the 12 case study agencies for providing detailed information on their scheduling practices. We gratefully acknowledge the guidance of the A-29 project panel and the guidance and assistance provided by Gwen Chisholm Smith of TCRP throughout the project.

FOREWORD

By Gwen Chisholm Smith
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TCRP Report 135: Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling is an update to *TCRP Report 30: Transit Scheduling: Basic and Advanced Manuals* and addresses contemporary issues in transit scheduling. *TCRP Report 135* provides information on available scheduling tools and techniques and their capabilities. Also, the report provides guidance to transit agencies on a variety of scheduling issues typically faced in a transit operating environment. The results of this research may be used by new or experienced schedulers, planners, operating managers, and chief executive officers.

TCRP Report 30: Transit Scheduling: Basic and Advanced Manuals was published in 1998. This was the first documentation of transit scheduling practices since the American Transit Association (APTA's predecessor) published the *Manual of Transit Scheduling* in 1947.

Although *TCRP Report 30* documented the state of the practice in 1998, there have been considerable changes in service design and scheduling practices since then. Specifically, transit agencies have increasingly turned to computer-assisted scheduling methods. Computer-assisted scheduling has the capability of refining operating schedules and work assignments to generate a highly cost-effective set of operator and vehicle assignments. This report provides updated guidance for transit-scheduling activities.

To assist in the development of *TCRP Report 135,* the research team conducted case studies to document, evaluate, and compare the merits of each type of work assignment used by small, medium, and large transit systems. The case studies include the pros and cons of using each assignment methodology.

In *TCRP Report 135,* the research team updates the basic and advanced sections of *TCRP Report 30* and includes a glossary that defines terminology and identifies common synonyms. *TCRP Report 135* addresses scheduling issues related to (a) service running times, (b) service recovery, (c) meal and rest breaks, (d) optimization of transfers, (e) clockface or memory headways, (f) through routing, (g) interlining, (h) headway-interval scheduling, (i) skip-stop and limited-stop operations, (j) long-route operating assessment, (k) part-time operators, (l) alternative work-week structure, (m) application of service level standards, (n) data integration, and (o) operator relief techniques and relative costs. Finally, *TCRP Report 135* discusses computerized scheduling system implementation issues.

CONTENTS

Summary

Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

Summary for Transit Managers, Executives, and Policy Makers

As a transit manager, executive, or policy maker you probably already know that schedule making is a vital function for your agency. Without accurate schedules, your agency would be unable to provide a reliable quality service to your riding public. Beyond the need for accurate schedules, your schedulers are vital to virtually every aspect of your agency, from finance to labor relations, and from planning to operations management. This summary distills five key reasons why scheduling is vitally important.

1. **Cost.** A good scheduler can reduce costs, with minimal impact on service levels or quality, in any economic environment. In times of expansion, schedulers can ensure that new service is being provided in the most cost-efficient matter. In times of belt-tightening, schedulers can identify opportunities to reduce costs while minimizing the impact on customers.

   How can schedulers do this? At the macro level, cost is a linear function of revenue hours of service, but at the detailed route level, cost is a step function that increases to the next step or decreases to the previous step only when a bus must be added to or can be removed from the schedule. Schedulers work at this detailed level and thus have developed innovative means to minimize costs along with a clear understanding of the critical factors that affect costs.

2. **Contracts and Labor Relations.** This understanding of the critical factors that affect costs is invaluable to a transit agency general manager, but is not always communicated clearly. The stereotype of schedulers is similar to that of accountants: wear green eyeshades (perhaps today this is replaced by "always at the computer screen"), analyze lots of data, not very sociable. Like all stereotypes, this is not universally true, but scheduling does attract people with a quantitative bent who would rather solve interesting mathematical problems than make small talk. It is well worth seeking their opinions on ways to control costs because of their detailed knowledge of critical factors.

   Schedulers' knowledge is especially useful at the bargaining table. Your schedulers have the most detailed understanding of anyone in your agency regarding the impacts of any current or proposed element of the collective bargaining agreement on cost and efficiency. Schedulers have too many stories of instances where the labor negotiating team agreed to a seemingly innocuous request for a change in the labor contract that ended up costing millions of dollars. Most of you already know this, but it is well worth repeating: always ask your schedulers to run the numbers first.

3. **Customer Service.** Senior management at one of the case study agencies noted that if you want to pay attention to customer service, then you have to pay attention to scheduling. To customers, a schedule provides the essential information needed to plan a trip, defines the arrival and departure times and the time the trip will take, makes sufficient capacity of service available so that the customers' trip will be comfortable, and ensures that customers will arrive at their destination at the promised time. The schedulers' work has a direct and significant impact on the quality of transit service.

4. **Work Environment.** The scheduling department defines the workday for your operators. Your operators, in turn, are the front line in terms of dealing with customers, and these interactions can be affected by elements of the schedule. Good schedules can reduce the stress inherent in this job, thus improving morale and minimizing absenteeism.

5. **Computerized Scheduling.** At this point, you may be thinking, "I approved a huge purchase for a computerized scheduling software package a few years ago—doesn't that address all of my scheduling issues?" This is one of the more common mistakes we see—the assumption that a computerized scheduling package is the solution, and not the tool. The truth is in fact the reverse. There is no substitute for the seasoned knowledge of a scheduling professional. As a colleague once put it: "You give a person MS Word and don't expect them to write the great American novel—so don't give them a computerized scheduling package and expect that they can produce high quality schedules!"

   Computerized scheduling provides many benefits: it frees the scheduler from many mundane and time-consuming tasks, its accuracy is unquestioned, and its speed permits more "what-if" testing of alternatives. However, scheduling cannot be reduced to learning another computer program. An experienced scheduler with a thorough knowledge of the craft knows how to tweak the program parameters and will explore different options on the way to designing the most efficient schedule.

While this manual is primarily geared for the scheduling professional, you may want to browse through it as well, or recommend it to others who are not directly assigned scheduling duties. The goal of this manual is to provide the reader with the skills necessary to be a professional scheduler, lacking only the years of practice needed to develop and apply the seasoning. Even those with no intention of becoming a scheduler can gain a greater understanding of what the scheduling process entails and how it can affect your agency's bottom line.

Chapter 1 provides a brief introduction to the manual. Chapter 2 discusses inputs to the scheduling process. Subsequent chapters address the individual elements of scheduling, including schedule building, blocking, runcutting and rostering.

Each of these chapters has basic, intermediate, and advanced sections. The advanced sections include discussions of contemporary, cutting-edge issues in scheduling. Virtually all of these issues affect your bottom line, either directly or indirectly. While written for the experienced scheduler, these discussions should be of interest to senior managers. A brief summary of the concepts and techniques included in each chapter is provided below

Chapter 1 – Introduction explains the purpose of the scheduling manual and discusses why scheduling is important.

Chapter 2 – Inputs to the Scheduling Process provides an overview of the scheduling process and describes external factors that affect a scheduler's work. Critical inputs include:

- Union contracts
- Route design
- Service standards

This chapter also discusses the organization of the scheduling department, required data, and data sources.

Chapters 3 through 6 address the four functional areas of scheduling. **Chapter 3 – Schedule Building** focuses on the process of preparing schedules. The basic level takes the prospective scheduler through all the steps involved in constructing a simple schedule, including span of service, headway, roundtrip cycle time, layover/recovery time, and the schedule pattern. These are the building blocks of any schedule, no matter how complex. The intermediate level shows how to adjust the basic schedule to accommodate different peak and off-peak headways and how to smooth the transition between time periods. The intermediate level also presents a more complex schedule for a two-branch route with different headways and running times throughout the day and demonstrates how to analyze data to determine whether service needs to be changed to meet demand and whether running times need to be adjusted. The advanced level works through actual headway and running time changes to an existing schedule.
Advanced topics include:

- Establishing running times
- Intertiming with even and uneven headways
- Joint consideration of running and layover times
- Running time myths

Chapter 4 – Schedule Blocking addresses the process of assigning trips to specific vehicles. The basic level discusses the importance of blocking within the scheduling process and blocks the simple schedule developed in Chapter 3. Specific topics include layover time, layover location, interlining/through routing, calculation of vehicle statistics, and graphing the blocks. The intermediate level blocks the more complex schedules from Chapter 3 and provides basic rules for blocking complex routes. The intermediate level also discusses how to evaluate a blocking solution and presents examples of reblocking the initial solution to be more efficient. The advanced level blocks the revised schedule from Chapter 3. Advanced topics include:

- Applying garages to each block
- Midday storage lots
- Interlining on a garage or system basis
- Route assignments by garage

Chapter 5 – Runcutting presents the process of converting vehicle blocks into work assignments for operators. The basic level discusses runcutting objectives, types of runs, runcutting inputs and outputs, the need to understand rules, constraints and practices, penalties and costs, operator reliefs, and means of evaluating a runcut. The basic level also presents an example of a runcut based on the simple schedule and blocking from previous chapters. The intermediate section presents a more complex runcut, and addresses the iterative nature of runcutting in recutting pieces of work and revisiting the blocking solutions. The advanced level considers more intricate runcutting challenges, such as more complex work rules, additional relief types and locations, and runcutting multiple routes and/or garages. Advanced topics include:

- Joint consideration of trips, blocks, and runs (emphasizing the interaction among all scheduling elements)
- Multipiece runs
- Meal breaks
- Relief types
- Overtime optimization
- Use of part-time operators and 4/10 work schedules
- Runcutting and computerized scheduling software packages

Chapter 6 – Rostering describes the process of grouping daily operator runs into packages of weekly work assignments. The basic level defines and discusses differences between agency-developed and cafeteria-style rostering, develops examples of both types and presents means of evaluating different rostering solutions. The intermediate level develops more complex rosters based on the schedules, blocks, and runcuts from previous chapters; discusses issues such as days off, impact of part-time operators, and five-day vs. four-day (4/10) rostering; and highlights factors related to rostering efficiency. The advanced level includes the following advanced topics:

- Revisiting run types
- Rotary rostering
- Rostering with spreadsheets and computerized software packages
- Extraboard considerations
- Holidays

The scheduling manual is oriented toward bus scheduling, but **Chapter 7 – Rail Scheduling** addresses the process of light rail and (briefly) heavy rail scheduling. Additional factors to consider in rail scheduling include yard balancing, adding/cutting cars, scheduling yard staff, and the impacts of terminal design on scheduling efficiency.

The **Glossary** includes a glossary of scheduling terms. Scheduling "language" has a wide variety of dialects. The manual includes a running glossary in the margins, but a grouping of common terms and variants in a glossary should prove beneficial for the transit industry.

Scheduling is not merely a production activity. One premise of this manual is that scheduling is the brain of the transit organism in its day-to-day function. By its nature, scheduling provides the clearest understanding of how and where cost efficiencies can be achieved in daily operations and of the impacts of specific provisions of the collective bargaining agreement on efficiency. It also clearly affects the service that operates on the street.

In summary, scheduling significantly affects service quality and significantly controls operating costs—probably the two key elements of a transit system. A savvy general manager makes full utilization of the scheduling department's knowledge in these areas, particularly during contract negotiations and in times of budget constraints.

Chapter 1.

Introduction to the Transit Scheduling Manual

schedule

A document showing trip times at time points along a route. The schedule may also include additional information such as route descriptions, deadhead times, interline information, run numbers, and block numbers.

layover time

The time between the scheduled arrival and departure of a vehicle at a transit terminal. Often used interchangeably with "recovery time," although technically layover time is rest time for the operator between trips while recovery time is time built into the schedule to ensure an on-time departure for the next trip. In this manual, layover and recovery are calculated together and the total time between trips is referred to as layover.

run

A work assignment for an operator. Most often, run refers to a whole day's work assignment.

Introduction to the Transit Scheduling Manual

Scheduling is both an art and a science, combining the best of creativity with pragmatism, elegance with mathematical precision.

We have a passion for scheduling! Why? Well, there are many reasons, but ultimately scheduling combines the best of creativity with pragmatism, elegance with mathematical precision. In a way, it is like a giant puzzle that looks indecipherable to the casual observer. Fans of Sudoku puzzles will understand this analogy. There is nothing more satisfying than to complete a **schedule** that is both efficient and provides the best possible service to the riding public at the service level required. You will hear a lot about this "maximize/minimize" philosophy as we get into the heart of the subject, for it is the essence of being a good scheduler.

Any type of training manual runs the risk of being tedious to read, clinical and informative but bland. We hope to infuse this with a bit of humor and also reveal a little bit of the passion on the way to helping the reader become one of the best schedulers.

Why is scheduling important? This question can be answered at several different levels.

- To customers, a schedule provides the essential information needed to plan a trip, defines the arrival and departure times and the time the trip will take, makes sufficient capacity of service available so that the customers' trip will be comfortable, and ensures that customers will arrive at their destination at the promised time. Senior management at one of the case study agencies noted that if you want to pay attention to customer service, then you have to pay attention to scheduling.
- To operators, scheduling defines the workday. Operators are the front line in terms of dealing with customers, and the interaction can be affected by running and **layover times**. Operators also tend to favor full-time **runs** and straight runs (as opposed to split shifts). Good schedules can reduce the stress inherent in this job, thus improving morale and minimizing absenteeism.
- To transit agencies, scheduling puts reliable service on the street where it will be most utilized. In addition, scheduling provides data and information to support other sections such as Marketing, Planning, Operations, Administration, and many downstream systems like AVL, APCs, voice annunciators, trip planners, and real time information systems.
- To general managers and chief financial officers, scheduling has major impacts on the quality and cost of operations. The extent of these impacts is sometimes not fully understood within the agency. Scheduling is the brain of the transit organism in its day-to-day functioning. By its nature, scheduling has the clearest understanding of how and

> where cost efficiencies can be achieved in daily operations and of the impacts of specific provisions of the collective bargaining agreement on efficiency. A savvy general manager makes full utilization of the scheduling department's knowledge in these areas, particularly in times of budget constraints.

What makes a good schedule? Reliability, service **frequency** that matches demand or agency policies, operating speeds as high as possible consistent with safety, and minimization of operating and capital costs are all important and at times contradictory goals. There are both art and science required in achieving these goals, beyond the requirement that the scheduler be capable of and comfortable with dealing with increasing reams of data. This manual explores both the science as well as the art of scheduling.

Today's scheduler has more tools at his or her disposal to take a lot of the drudgery out of the process. But he or she also faces more challenges. Deadlines are often much shorter as a result of what can be, at times, a politically driven service implementation process. There are now ever more downstream customers for scheduling material. At one time, a schedule department was also a print shop, but much of the finished schedule information is now needed in electronic form. This means that scheduling purely by hand is no longer practical, even for small transit properties, where keeping on-board electronic gadgets such as next stop annunciators up to date can take longer than the regular scheduling process.

And yet, today's highly efficient computerized scheduling software packages, while supplying all these downstream requirements quickly and accurately, tend to mask the whole scheduling process, especially for beginners. The practice of scheduling is becoming a case of learning another computer program and manipulating the program to get results within the guidelines of the parameters programmed into it. The whole theory of the underlying practice has been lost to many of today's schedulers.

This manual is intended for use by those interested in learning more about the scheduling process, whether you schedule manually[1] or via computerized scheduling software packages. The manual will be especially useful for the latter group, by introducing the craft of scheduling to schedulers who may view the software as a "black box."

From our observations, many schedulers receive the training they need to operate the specific software packages but very little in terms of the scheduling craft. The outcome is that schedules are being produced that are technically efficient in that they meet the parameters defined

Tip An automated scheduling package can produce the "science"—creating an accurate and conforming schedule, but no automated package will ever replace the artistry of a well-constructed schedule created by an enlightened and practiced scheduler.

frequency

The number of vehicles passing a point on a route within a given unit of time, usually expressed as X vehicles per hour. See also "headway." Headway is the inverse of frequency: a frequency of six buses per hour is equivalent of a headway of 1/6 hour or 10 minutes.

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[1] An assumption throughout this manual is that scheduling "by hand," using pen and paper, no longer exists. "Scheduling manually" in this context is therefore defined as scheduling undertaken not using proprietary computerized scheduling systems but using basic tools such as spreadsheets, word processors, and database programs.

within the software but not as competent or even as practical as they could be if developed with a thorough knowledge of the craft of scheduling.

We take the view that a computer and scheduling package should be thought of as a tool…a very useful and powerful tool, but one that must be applied with the seasoned knowledge of a scheduling professional. As a colleague once put it: "You give a person MS Word and don't expect them to write the great American novel—so don't give them a computerized scheduling package and expect that they can produce high quality schedules!"

> *A good schedule provides the right level of service at the minimum cost. A good schedule is the key to an efficient and sustainable transit operation.*

The goal of this manual is to provide the reader with all of the skills necessary to be a professional scheduler, lacking only the years of practice needed to develop and apply the seasoning. We pledge to try and make the reading interesting and informative along the way. Even if you have no intention of becoming a scheduler, we still welcome you to this manual as a way to gain a greater understanding of what the scheduling process entails and how it can affect your agency's bottom line.

This manual is designed to focus on bus scheduling. Rail schedulers will still find sections with information specific to their particular mode. However rail scheduling (particularly timetabling) has many unique aspects that are beyond the scope of this project.

One last note before we begin: we certainly do not want this manual to be any more mystifying than it needs to be. A constant issue the industry faces is non-schedulers' reluctance to deal with scheduling issues, due to its reputation as a difficult, unfathomable subject. Scheduling, like all other specialized practices, has a language of its own, with specific terms that may not be familiar to newcomers or even transit employees who are not involved with scheduling. Even worse, these terms are not universal: individual transit systems have their own "dialect" or unique names for things. For example, once the schedulers have completed their tasks, work assignments are posted for operators to select. This is called a pick, line-up, shake-up, bid, sign-up, or mark-up, depending on the agency.

As much as possible, we use the most widely used term in the discussions that follow. The margins contain a running glossary, defining a term the first time it is used. The reader can also refer to the Glossary, where every term we and others have been able to collect over the past two decades is defined.

Chapter 2 discusses inputs to the scheduling process. Subsequent chapters address the individual elements of scheduling:

- Chapter 3: Schedule Building
- Chapter 4: Schedule Blocking
- Chapter 5: Runcutting
- Chapter 6: Rostering
- Chapter 7: Rail Scheduling

The chapters have basic, intermediate, and advanced levels. At the end of each section, you will have the choice to continue along in the same section of the following chapter or to move on to a higher level within the topic.

Chapter 2.

Inputs to the Scheduling Process

route

A defined series of stops along one or more streets between two terminal locations designated by a number and/or a name for identification internally and to the public.

running time

The time it takes for a vehicle to travel the length of a route or between two specific points on a route. Running time does not include layover time.

2.1 Introduction to the Scheduling Process

Scheduling requires a series of judgments that are based on a thorough understanding of your particular transit system and its policies and labor agreements.

As with everything else, it is best to start at the beginning, and that means building a strong foundation for a schedule before ever beginning work on the schedule itself. The old saying, “a house is only as good as its foundation” applies here, whether you are making a new schedule or revising an existing schedule.

Schedulers cannot work in isolation and need to be aware of the issues surrounding their work as well as the objectives and goals they are trying to achieve. Typically this requires an understanding of the transit agency, its policies, structures, issues, and goals.

So, what are the foundations of a schedule? These can be reasonably categorized into two types of requirements:

1. Those things external to developing a schedule but required for proper schedule development. The kinds of items that would be included in this category are:
    - Knowledge of budgetary constraints
    - Knowledge of your transit system’s goals
    - Knowledge of the area being served
    - Knowledge of your agency’s current short- and long-term objectives/goals

2. The data elements or inputs required to actually construct the schedule. Those encompass:
    - Knowledge of the scheduling provisions of the collective bargaining agreement
    - **Route** design considerations
    - Service standards
    - Annual Service Plan
    - Service data, including **running time**, patronage, and operations

The last item is critical to the task at hand and presupposes the other items on the list are readily available and well understood. Some of these items may not be familiar to those new to scheduling, but keep in mind that this is an introductory chapter providing a broad overview of the scheduling process. Subsequent chapters include much more detailed discussions.

2.2 External Factors

The first four requirements have the word “knowledge” in them. This is a reminder that there is no substitute for knowing your individual transit agency’s or company’s policies, service budgets, goals and objectives, and the areas served. These underlie all aspects of schedule development. This manual assumes you are familiar with your agency’s policies as well as your routes and how they interact with each other. A detailed working knowledge of the transit system is one of the most fundamental requirements for a scheduler. This understanding assists in making the many value judgments that are required during the scheduling process.

Fieldwork is very helpful in keeping your knowledge of your system up to date. The kinds of things that you should look for when you are out in the field include: how adequate is the running time; what do the **passenger loads** look like at various points along the route; where are places that cause potential delays; is there a better place to turn around at the end of the route; are the number of wheelchair boardings greater than what would be considered average for other routes on the system. Getting out of the office once in a while also is a good change of pace from the routine. As Yogi Berra once said, “You can observe a lot by watching.”

The last three decades of government financial assistance have brought a uniformity of practices to most transit organizations. This has served to produce documents that set standards for schedulers. Such documents as the Five Year Service Plan and its annual updates establish or update route design criteria and **service standards**. A financial plan goes hand in hand with the Five Year Service Plan. It may call for expansion of service, service reductions, or both at the same time, depending on the goals of the service plan and the realities of the available funding. Sometimes circumstances will change quickly during a budget year, requiring major changes to the service. The scheduler must be aware of the general direction of the transit system; these strategic reports are a useful source of information.

passenger load

The number of passengers carried on one or more vehicles at any point on a route. Of particular interest is the maximum passenger load on a route or segment.

service standards

Performance requirements expressed in system policies. Service standards are normally established in areas such as cost efficiency (cost per unit of service), service effectiveness (boardings per unit of service), cost effectiveness (cost and subsidy ratios), passenger loading, and schedule adherence. Many agencies also have service policies that guide the development of routes and schedules. Also known as “service guidelines.”

branch

One of two or more outer route segments served by a single route.

2.3 Inputs to the Scheduling Process

Union Contracts—Collective Bargaining Agreements

Union contracts or collective bargaining agreements carry specific requirements that affect how service is scheduled, blocked, and cut into driver runs. Even systems that have no union tend to have their own rules that have developed over time. Much will be said later about labor provisions, but we assume that you have read the contract and have highlighted those sections pertinent to the scheduler.

Beyond the union contract are agency scheduling practices or preferences. Questions such as "do we prefer to avoid interlining?", "is our operating practice to avoid street reliefs after 7 PM?", or "do we prefer not to schedule runs too close to maximum allowable spread time?" cover typical non-contract issues. In most cases there are many preferences and practices not covered in the labor contract, and these need to be understood.

Route Design

Depending upon the structure and size of your agency, as a scheduler you may or may not be responsible for (or have input into) design of routes. Either way, it is important to understand at least the basic principles in route design as they significantly affect the entire scheduling process.

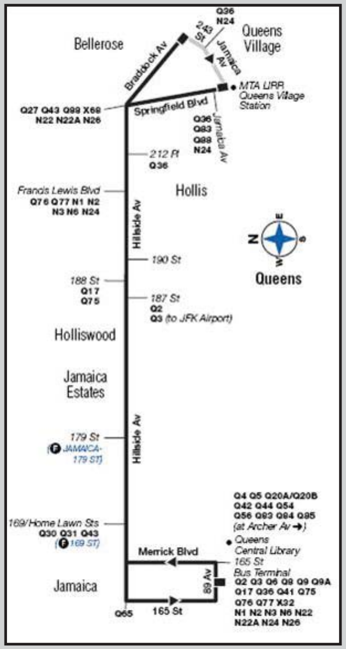
The extent of route changes varies widely from system to system. The route network may remain static or may be subject to varying levels of change. While schedulers overwhelmingly work on existing routes, they will be called upon at some point to build a schedule on an entirely new route and may be expected to add their expertise to the final design of the route. Service planners can plan routes that meet their exacting criteria, but it is up to the scheduler to make the route work operationally. An ongoing dialogue between schedulers and service planners is necessary to develop routes and schedules that meet an agency's objectives.

An important element of making a route work operationally is running time. The scheduler's goal is to find the happy medium between too much and too little scheduled running time to ensure reliability and efficiency in daily operations. This will be discussed in much greater detail in subsequent portions of the manual. Practical concerns such as identifying restroom opportunities at the ends of routes are also important in route design.

Route design also encompasses certain elements that either keep the route simple or add complexity. Some of these are:

Branches

Do we allow for one or more **branch** routings, normally at the outer end of the route? If so are the branches of equal length? Unequal branch lengths can become a source of inefficiency in a schedule, particularly at wide **headways**, such as 30 minutes or longer. The route on the left has two branches of equal length. The common portion of a route with branches is the **trunk**. Branches also affect the time spent on basic route definition tasks in scheduling packages, which need high levels of accuracy for downstream systems.



The branch example above has two branches at its eastern (top) end: via Braddock Ave. and via Springfield Blvd.

headway

The interval of time between two vehicles running in the same direction on the same route, usually expressed in minutes. See also "frequency." Frequency is the inverse of headway: a headway of 10 minutes is equivalent to a frequency of one bus every ten minutes or six buses per hour.

trunk

The common portion of a route with branches; more broadly, a section of a corridor served by multiple routes or trip types.

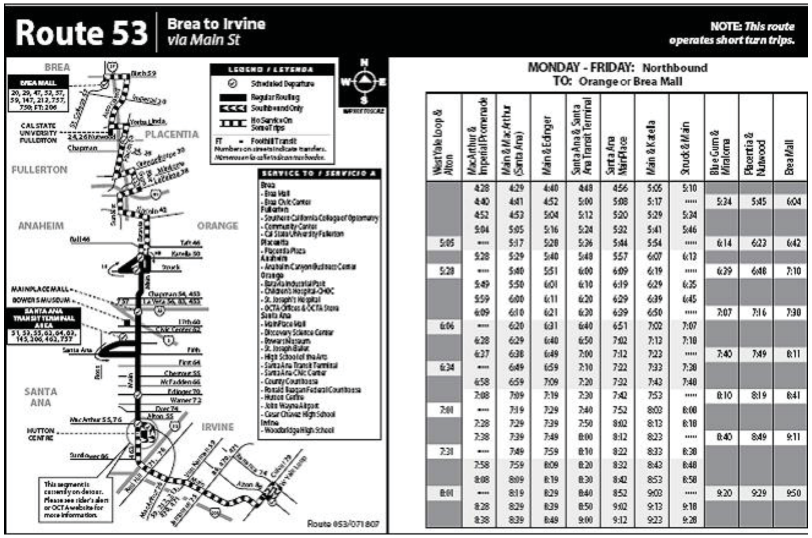
Route Deviations

These may incorporate different paths in the middle of the route, either as an alternating service pattern (the route above on the right is an example), as occasional trips (e.g., serving a school at bell times), or as time of day based service patterns (e.g., deviating into a shopping center during open hours). These may be combined with branches, which can further complicate the schedule, particularly if the scheduler mixes and matches the alternate trips with the branch trips.

Short Turns

These are points were the service ends short of the end of the route. These points may be selected by schedulers or planners and should ideally be chosen at a point that is some multiple of the running time and headway, unless **interlining** is allowed to offset. Otherwise, layover that is longer than necessary can result. They also ideally are at a point where on-board ridership is half or less than the number the schedule was designed to handle at the peak load point to avoid overloads on long trips. The turnback should be at a place where the bus can take layover without obstructing traffic and where it can easily turn around for the return trip. Finally, a **short turn** should be instituted only if it reduces peak bus requirements for the route. We will give an illustrative example of what must be considered in scheduling **turnbacks** when we examine more complicated schedules later in this manual.

Below is an example of a route with short turns in both directions. The solid line shows the "core" route between the turnback locations, while the dotted lines show the full route.



Route 53 Brea to Irvine *via Main St*

NOTE: *This route operates short turn trips.*

LEGEND / LEYENDA
- Scheduled Departure
- Regular Routing
- Southbound Only
- No Service On Some Trips
- FT - Foothill Transit
- Numbers on streets indicate transfers.

SERVICE TO / SERVICIO A
- Brea
  - Brea Mall
  - Brea Civic Center
- Fullerton
  - Southern California College of Optometry
  - Community Center
  - Cal State University Fullerton
- Placentia
  - Placentia Plaza
- Anaheim
  - Anaheim Canyon Business Center
- Orange
  - Batavia Industrial Park
  - Children's Hospital-CHOC
  - St. Joseph's Hospital
  - OCTA Offices & OCTA Store
- Santa Ana
  - MainPlace Mall
  - Discovery Science Center
  - Bowers Museum
  - St. Joseph Ballet
  - High School of the Arts
  - Santa Ana Transit Terminal
  - Santa Ana Civic Center
  - County Courthouse
  - Ronald Reagan Federal Courthouse
  - Hutton Centre
  - John Wayne Airport
  - Cesar Chavez High School
- Irvine
  - Woodbridge High School

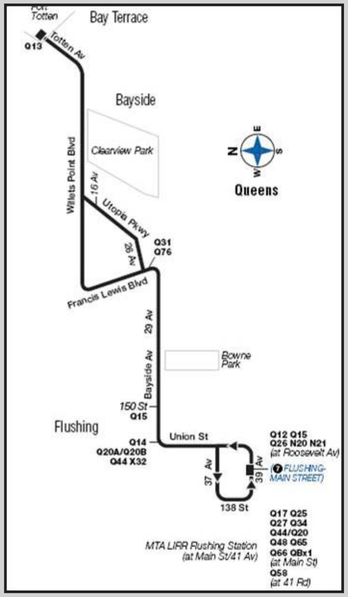
This segment is currently on detour. Please see rider's alert or OCTA website for more information.

Route 053/071807

MONDAY - FRIDAY: Northbound
TO: Orange or Brea Mall

West Yale Loop & Alton	MacArthur & Imperial Promenade	Main & MacArthur (Santa Ana)	Main & Edinger	Santa Ana & Santa Ana Transit Terminal	Santa Ana MainPlace	Main & Katella	Struck & Main	Blue Gum & Miraloma	Placentia & Nutwood	Brea Mall
	4:28	4:29	4:40	4:48	4:56	5:05	5:10			
	4:40	4:41	4:52	5:00	5:08	5:17	-----	5:34	5:45	6:04
	4:52	4:53	5:04	5:12	5:20	5:29	5:34			
	5:04	5:05	5:16	5:24	5:32	5:41	5:46			
5:05	-----	5:17	5:28	5:36	5:44	5:54	-----	6:14	6:23	6:42
	5:28	5:29	5:40	5:48	5:57	6:07	6:13			
5:28	-----	5:40	5:51	6:00	6:09	6:19	-----	6:39	6:48	7:10
	5:49	5:50	6:01	6:10	6:19	6:29	6:35			
	5:59	6:00	6:11	6:20	6:29	6:39	6:45			
	6:09	6:10	6:21	6:30	6:39	6:50	-----	7:07	7:16	7:30
6:06	-----	6:20	6:31	6:40	6:51	7:02	7:07			
	6:28	6:29	6:40	6:50	7:02	7:13	7:18			
	6:37	6:38	6:49	7:00	7:12	7:23	-----	7:40	7:49	8:11
6:34	-----	6:49	6:59	7:10	7:22	7:33	7:38			
	6:58	6:59	7:09	7:20	7:32	7:43	7:48			
	7:08	7:09	7:19	7:30	7:42	7:53	-----	8:10	8:19	8:41
7:01	-----	7:19	7:29	7:40	7:52	8:03	8:08			
	7:28	7:29	7:39	7:50	8:02	8:13	8:18			
	7:38	7:39	7:49	8:00	8:12	8:23	-----	8:40	8:49	9:11
7:31	-----	7:49	7:59	8:10	8:22	8:33	8:38			
	7:58	7:59	8:09	8:20	8:32	8:43	8:48			
	8:08	8:09	8:19	8:30	8:42	8:53	8:58			
8:01	-----	8:19	8:29	8:40	8:52	9:03	-----	9:20	9:29	9:50
	8:28	8:29	8:39	8:50	9:02	9:13	9:18			
	8:38	8:39	8:49	9:00	9:12	9:23	9:28			

An example of a route with short turns in both directions. The solid line shows the "core" route between the turnback locations, while the dotted lines show the full route.



This route deviation example has a mid-route deviation, with trips alternating via Utopia Pkwy and Francis Lewis/Willets Point Blvds.

short turn

A trip that terminates at an intermediate point instead of traveling the full length of the route. Short turning is frequently used to add capacity to a specific segment of the route.

turnback

The location where a short turn trip turns around to begin service in the opposite direction.

interlining

The use of the same vehicle on a block operating on more than one route with the same operator, without returning to the garage during route changes.

bus rapid transit (BRT)

A form of bus service that, through improvements to infrastructure, vehicles and scheduling, is intended to enhance service quality compared to an ordinary bus line. Features may include exclusive right-of-way, signal priority, widely spaced stops, higher capacity vehicles with special branding, stations, headway-based schedules, and off-bus fare collection.

express service

A service generally connecting residential areas with activity centers via a high-speed, non-stop route with limited stops at each end for collection and distribution. Park-and-ride lots are a common feature of express service at the residential end of the route.

limited-stop service

A service typically operating on arterial streets that makes stops only at major points along the route. Similar to express service, but without a lengthy non-stop segment.

hooking

The process of attaching the end of a trip in one direction to the beginning of a trip the other direction. A block is a series of hooked trips.

Loops

These can cover the outer or inner end of a route, or the whole route itself can be a loop, either in one direction or bi-directional. Large loops at the ends of a route have the advantage of service to a larger area with just one route, but can cause long out-of-direction passenger movements. Loops are also a headache for the scheduler. Where to put the layover? Wherever you place it—before, after, or in the middle of the loop—someone riding in the "wrong" direction will have to sit on the bus during the layover. One way around this dilemma is to schedule all layover time at the non-loop end of a looped route.

Express, Limited, or Bus Rapid Transit (BRT) versus Local Operation

Routes in larger cities may have enough ridership to be able to operate two classes of service for all or part of the day. These different types of service operating on the same corridor have different stopping patterns, running times, and perhaps even **time points**. The complexity of scheduling local and **express services** requires an understanding of their interaction in an operational sense, and will be addressed later.

Through-routing

This is the process of combining routes on different sides of a central area, usually done to achieve efficiencies in use of equipment, reduce the need for layover space, simplify routing by reducing the number of turns required, and reduce the number of trips operating through the central area. **Through-routing** in this manual refers to the full time operation of two routes as a single route for all practical purposes. Interlining is defined as a random or systematic **hooking** of individual trips. Some systems mix up these two distinctions or see them as interchangeable, but we will keep them separate in this manual according to the above rule to avoid confusion.

In addition to the design concerns noted here, a route needs to be planned at an operational level to check issues such as turns and clearances, to make certain that all streets shown on the planning map are actually continuous and any bridges can support the weight of a bus. Never rely solely on a map!

Cycle Time

At the risk of getting ahead of ourselves, we include **cycle time** here as a strong consideration in determining routing. Again we emphasize the need for the scheduler and planner to work collaboratively to ensure all outcomes are sufficiently understood to make informed decisions.

Let us provide an example—in this case a stand-alone route operating on a simple service pattern of operation with low frequency and consistent running time throughout the day. If the running time is 54 minutes either way and the headway is 60 minutes, the route schedules efficiently. However, what if an extension of 7 minutes is proposed?

Part of the decision-making process must be an understanding that the impact of the route design change will be an increase in operating costs of one vehicle. This is often not well understood at a generic planning level, where it is sometimes assumed that a 13% increase in route length (the 7 minutes added onto the existing 54) will result in a 13% increase in operating cost. This is not so! For simple operations such as this, the cost is a step-function which increases significantly each time a cycle time threshold is reached.

Obtaining Mileage

The scheduler is required to calculate route distances for a range of purposes. Whether scheduling manually or using a computerized scheduling package, mileage is used as an input at the route level to provide totals at a schedule level.

Even if scheduling manually, mileage can be calculated using basic “off the shelf” geographic information system (GIS) mapping systems. Furthermore, simple tools such as “Google Maps” allow distances to be calculated with a high degree of accuracy and with little effort. Older methods still in use include mileage measurement from a paper map with a flexible tape measure or a map wheel and measurement in the field using vehicle odometers.

If using a scheduling software package, mileage is an input to the program, which then automatically calculates total mileage based on trip patterns and **deadhead** mileage. As of this writing, nearly all computer software packages also provide a built-in mapping routine which allows the scheduler to input the route and its various service patterns and obtain accurate mileage from the map. The program then automatically generates total mileage for the finished schedule.

An added benefit of using the scheduling package for obtaining mileage is the fact that mileage between bus stops can be accurately derived. This information is much more necessary now than in the past because it forms the input for such downstream applications as automatic stop announcement systems (voice annunciators). Some transit systems have the need to break mileage down by political jurisdiction, so this feature comes in handy for them as well. The information can be obtained by the other methods mentioned earlier, but this is true drudgery work of the type that computers were invented to relieve. In fact, automated mileage calculation is one major improvement since the all-by-hand scheduling era.

No matter which method is used, the information needs to be broken down for each time point-to-time point segment, or even at a stop-to-stop level (which is then aggregated at time point-to-time point and route levels). These segments can then be accumulated into **service patterns**, as

time point

A designated location on a route used to control the spacing of vehicles along the route. As a rule, vehicles should not pass through a time point either before or after the specified time on the schedule. A route may contain several time points depending on its overall length. As a rule of thumb, time point spacing is usually every seven to 15 minutes along a local route, and time points are designated where possible at major intersections, major trip generators, and key destinations.

through-routing

A form of interlining in which a vehicle switches from inbound service on one route to outbound service on another route while continuing in service throughout the day.

cycle time

Equals the round trip running time plus layover time. This is also known as “round-trip cycle time” or “round-trip time.”

deadhead

The time and distance that a bus needs to travel in places where it will not pick up passengers. Deadheading is typically required to get buses to and from their garage, or when bus operators need to travel from one route or point to another during their scheduled work day.

service pattern

The unique sequence of stops associated with each type of trip on a route. If all trips operate from one end to the other on a common path the route has one service pattern. Branches, deviations or short turns introduce additional service patterns. Service patterns are a fundamental component of scheduling and provide the framework for tracking running time, generating revenue trips, and identifying deadhead movements for the route. Also referred to as "trip pattern," "variant," or "path."

platform time and mileage

A phrase derived from the early 20th century days when motormen and conductors operated from the "platform" of a streetcar, platform time (or platform miles) includes all time or distance travelled when the operator is operating the vehicle. Layover time and pull-in and pull-out time and distance are part of platform time and mileage, but report allowance and clear allowance are not. Similarly, platform miles include all miles traveled while the operator is operating the vehicle.

each separate way of serving a route is called. The number of trips for each service pattern can be multiplied by mileage for that service pattern and then simply summed into a total for that particular schedule.

Mileage is always divided between revenue and deadhead mileage. The former includes all miles when the bus is actually operating in passenger-carrying service. The latter is accumulated during times of operating to and from the garage or in operating out of service from one point on one route to another point, either on the same route or on another route. Deadhead mileage is often broken down into garage deadhead mileage (all mileage operating to and from the garage as a deadhead trip) and interline deadhead mileage (all mileage on deadhead trips that are generated as a means of linking one trip to another). Together, revenue and deadhead mileage constitute **platform mileage**.

Geocoding

Geocoding is the process of obtaining the latitude and longitude of an exact location from a map. This approach is overkill for merely obtaining mileage for route segments, but becomes more critical when the exact locations of bus stops have to be known [typically important for downstream systems such as automatic vehicle location (AVL), automatic passenger counter (APC), voice annunciation etc.]. Using GIS software or the mapping routines built into scheduling software packages, an exact lat-long fix can be obtained for every bus stop, including multiple bus stops at major intersections. There are many uses for this information; two examples are (1) bus stop databases, which also store detailed information about the stop, and (2) automated bus stop announcement systems. The latter make use of satellite technology to know the bus' exact location along a route and its proximity to the next stop. The "next stop" announcement is triggered at a certain distance from the stop. This technology is highly useful in meeting the requirements of the Americans with Disabilities Act and would not be possible without the ability to geocode the route and stops.

Scheduling software with mapping capabilities has other uses that can save schedulers time. Many can automatically generate the most efficient routings between starting and ending points on a route and the garage, inclusive of updating the database containing running times and mileage. This practice must of course be tempered by an understanding of the road network (e.g., avoiding narrow residential streets) and key congestion points. Ultimately the scheduler should review all outputs from such tools and adjust as necessary.

Service Standards

Many transit systems publish service standards. These set forth, often in great detail, minimum service levels (known as policy levels) by time of day and day of week. Where demand requires service greater than these policy levels, the standards specify minimum and acceptable load factors, which in turn determine headways. These standards can simplify some aspects of the scheduler's job by providing quantitative guidance in key areas.

Service standards are typically set at a strategic planning or service planning level, but form a major input into the scheduling process. These standards may be formally adopted or may just be a working copy of a compilation of actual practices your system has developed through the years. The discussion below covers some key items that are probably contained in your system's service standards.[1]

Service Days

What type of service is operated on each day of the week? Monday through Friday schedules are common, but that was not always the case. Many systems use a different Friday schedule on some routes where traffic is particularly slow or where service operates later at night. Does the system operate on Saturday and Sunday? The service may or may not be the same on these days.

On larger systems, is there a holiday or otherwise reduced schedule operated on designated holidays? Many systems operate Sunday schedules on "major" holidays. Major holidays are generally defined as New Years Day, Memorial Day, July 4, Labor Day, Thanksgiving Day, and Christmas Day. However, there are increasing demands to reduce service on so-called minor holidays, such as Martin Luther King, Jr.'s Birthday, the day after Thanksgiving, and Christmas Eve. Add to those regional holidays, such as Good Friday or Easter Monday, Columbus Day, Election Day, Veterans Day, and Presidents Day. How these are handled is designated in the Service Standards.

Span of Service

What are the operating hours of the route? Do the operating hours differ on weekdays from those designated for Saturdays and Sundays? What are the criteria for operating night service on a particular route? Do the operating hours apply to the whole length of the route, or all the branches?

Policy headways

A large share of service at many properties is determined by "policy headways." Policy headways set minimum service levels by policy rather than by capacity and demand; for example, all routes might operate every 30 minutes in peak hours and every 60 minutes in off-peak hours. For policy-based headways, there should be a standard defining when ridership levels would justify added service. Policy headways can also be used to identify a minimum frequency of service. For example, a system could decide that each route would operate at least every 60 minutes.

Tip Frequency and headway are both used to define the amount of service provided, but increasing frequency (e.g., from 5 to 6 trips per hour) is the same as reducing the headway (from 12 to 10 minutes). Remember that reductions in headway actually increase the amount of service provided.

span of service

The length of time, from the beginning of the first trip to the end of the last trip, during which service operates on the street. Span of service can be expressed for a route or for the system as a whole.

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[1] For a more complete overview of service standards, see TCRP Synthesis Report 10, Bus Route Evaluation Standards.

loading standard

The agency-established goal for passenger loads (not the maximum vehicle load, which is considerably higher). The loading standard is usually expressed as a percentage of seated capacity, as the maximum number of standees, or as the maximum load. The loading standard often varies over the day, with peak-period loading standard higher than off-peak periods. Some agencies also specify a time or distance duration that certain loads are allowed (e.g., 150% for up to 10 minutes). The loading standard is used to calculate demand-based headways during the various periods of the service day.

peak periods

The hours during which ridership is highest, usually in the morning and afternoon commute times (e.g., 6 to 9 AM and 3 to 7 PM). Sometimes expressed as peak hour, the hour of highest ridership, it can also refer to the period during which the most frequent service is operated, e.g., peak 20 minutes.

base period

The hours between the AM and PM peak periods, during which ridership is generally lower than in peak periods. Also known as “midday” or “off-peak period.”

Loading Standards

The alternate approach to determining headways is demand-based, where the passenger loads dictate the headways to be operated. Target loads are specified for different types of routes during different times of day. For example, **loading standards** might call for average loads of 50 during **peak periods** and 40 during the **base period**. Some loading standards may be expressed in other ways, such as percentage of seated capacity, number of standees (if any) allowed, or standees per available floor space. Schedulers and planners use detailed ridership data to adjust headways so that the average peak load matches the standard (a simple division calculation in most cases). Depending on frequency of service, averages may be calculated for each hour, each half-hour, or each 15-minute period.

Standards for Types of Equipment

Vehicle type or size can be dictated by many factors. These include passenger loads, accessibility, the road network, and capacity requirements. Scheduling may have the role of assigning equipment to each route or to individual blocks in each route and therefore needs to be familiar with the characteristics of each type of equipment, primarily seating and standing capacity. This task may be at the discretion of the scheduler or be mandated within the service specification. The increasing popularity of low-floor buses, which have fewer seats than standard buses of the same length, has complicated the application of loading guidelines. Loading standards may be specifically called out for each type of bus, or may be set as a percentage of seated capacity.

Among the choices found on many systems, besides the standard 40 foot bus, are:

35 foot buses—ideal where loads are moderate and route clearances may be a problem.

29 to 30 foot buses—used on many shuttles serving residential neighborhoods where boardings are light; perceived as more “neighborhood friendly”.


45 foot “cruiser” bus

24 to 27 foot “cutaways” (body on chassis, van or truck)—same applications as 29 to 30 foot buses, only with yet smaller vehicles. Some cutaways are now over 30 feet long.

60 foot articulated buses—deployed on heavier routes where the added carrying capacity can allow for wider headways and fewer operating resources to provide the same number of seats. Not in common North American use, but similarly deployed, are double-deck buses.

45 foot “cruiser” buses (“over the road” coaches)—an increasingly popular model for express and park-and-ride service. Because of the high floor, number of steps and one-door configuration, they are not workable for local line service.

Criteria for Adding or Eliminating Trips

The amount of service provided, both in terms of service span and frequency, is often dictated by economics. However, a well designed system matches the level of service to service demand. Underserved routes may be overcrowded and may cause some riders to choose other modes. Overserved routes are characterized by empty buses that could be better used somewhere else. Some routes are overserved over some portion of the route and underserved elsewhere. There is a temptation for public transit operators to be complacent in establishing standards for when service or parts of service should be added or eliminated based on productivity. Ideally, for each service review, planners and schedulers have the ability to ask: "If I were to start this route from scratch, applying all good planning principles, is this the level of service I would operate?"

Criteria need to be included in the service plan to set out how under-performing routes or segments will be eliminated. One particular system considers that any trip toward the end of the operating day regularly carrying less than five passengers is subject to being eliminated. Of course this number can vary according to the resources of the individual system. Also, circumstances such as ridership on adjacent trips must also be considered. Often the last trip on a route is operated as a safety valve: it may have few regular riders, but it serves those who are delayed at work or elsewhere on any given day.

Other Considerations

Service standards might also dictate that headways be "clockface" wherever possible. Clockface headways are those that evenly divide into 60 minutes and are capable of providing leaving times at the same time each hour. The pros and cons of this are explained later, but a quick summary would list ease of understanding for the customer as the major benefit and potential scheduling inefficiencies as the major disadvantage.

Timed transfer requirements may also be explicitly stated by agency service standards, including locations and **transfer window** requirements. The scheduler is usually not concerned with route spacing, but it is normally part of a service standards package. The amount of the **service area** that is within the route catchment area (i.e., within a half-mile or quarter-mile walk, or some other mandated criteria) may also be specified. GIS tools make the identification of such areas relatively simple. Finally, much of the previous discussion on route design is usually embodied in the service standards as well.

Many transit systems consider unmet needs at regular intervals. These are often incorporated into early action plans that call for route expansion whenever operating budgets will allow. The scheduler, working with the service planner, needs to be aware of these and incorporate them into a service budget when planning an annual list of service changes.

timed transfer

A transfer made easier and more certain for passengers by the process of scheduling two or more routes to meet at a given location at a specific time. A short layover may be provided at the timed transfer point to ensure that connections can be made even if one vehicle is running slightly behind schedule. Timed transfers have become more important with the growth of hub-and-spoke network designs.

transfer window

The layover time scheduled at timed transfer locations to ensure that transfer connections can be made, and may also refer to the amount of time past its scheduled departure time that a vehicle can be held at a transfer location to wait for a late arriving vehicle.

service area

Broadly, the area in which a transit agency provides service. This may also be defined as the area within a convenient walking distance (such as ¼ mile) of a route or a stop. For the purposes of compliance with the Americans with Disabilities Act, service area is the area within ¾ mile of a fixed route service.

sign-up	The process in which operators select work assignments. Most agencies have three or four sign-ups each year.
sign-up period	The period of time that a specific sign-up is in effect, usually three or four months.
vehicle hours	Total hours of travel by a vehicle, including hours in revenue service (including layover time) and deadhead travel. Also known as “bus hours” for bus. “Car hours” is the term used for rail.
mode	A type of transit service characterized by vehicle or operational features. Common transit modes include motorbus, trolleybus, light rail, heavy rail, commuter rail, and demand-response.
exception scheduling	Scheduling activity undertaken to address major construction detours or delays, sporting events, holiday service, or other special situations.

Annual Service Plan

An annual Service Plan is not something that is uniformly prepared and followed, but it is a decided advantage to the scheduler. An annual service plan, which can exist as an Operating Plan or a Service Budget, takes the proposed service changes, additions and deletions and incorporates them into a time framework that takes into account the **sign-up** process (when operators pick their work assignments). An ideal format for an Annual Service Budget, as developed at one large transit agency, lists service additions, discontinuations and adjustments chronologically for each **sign-up period** during the upcoming year along with an estimate of the **vehicle hour** impacts. It also carries a line item called “augmentation” which includes non-allocated hours set aside for trip increases to correct overcrowding on peak-only routes, such as park-and-ride express routes. The schedulers also have latitude to eliminate trips or peak hour buses from underperforming lines and use these resources to add where they are better needed. Seasoned schedulers will often refer to having adjustments “in their pocket,” which means they already know where they can reallocate or cut hours if the budget requires it.

At most systems, the sign-up process occurs three to four times a year. The advantage of this is two-fold; (1) the scheduler can plan their work for a complete year and (2) they can work within very close estimates of what the annual budgeted operating hours and/or miles will be. This becomes critical at a time when major service cuts must be made to meet unanticipated budget shortfalls.

2.4 Organization of Scheduling Departments

A question that is often posed is “what is the ideal size and composition of a scheduling section of a modern day transit system?” The answer requires a great deal of input information and includes some of the following criteria:

- How often does the service change/How many bids per year?
- How much service changes each time?
- Are there multiple **modes**?
- Does **exception scheduling** account for significant amount of scheduling time?
- How large are the garages and how many are there?
- To what extent are schedulers required to undertake service planning work?
- Do schedulers prepare rosters?
- How large is the transit system (the schedulers-to-bus ratio is not simply a straight line function)?

- To what extent are schedulers responsible for maintaining data for downstream systems?
- How complex or constrained are the work rules?

In short, the factors that define scheduling department size are far too numerous to allow a simple standard. If there is truly an average out there, it is one scheduler per operating garage. A garage on a medium to large transit system can store anywhere between 100 and 500 buses, with the average being between 150 and 250 buses. Schedulers may employ a few assistants.

The scheduling department will invariably include staff with a range of experience and skills. As a result, a natural experience-based hierarchy can be derived. In addition to schedulers there may be scheduler trainees or interns, scheduling analysts or similarly named positions, one or two senior schedulers, and the head of the section. Additional support staff may be needed to perform a growing number of ancillary functions, such as programming headsigns and automatic stop annunciator systems and keeping up the bus stop list.

At some systems (typically smaller agencies), schedulers are responsible for carrying the whole task of building a new schedule through from analyzing the traffic checks to the finished runcut and roster or bid package. At others, schedulers schedule and senior schedulers perform the runcutting, which is considered to require the work of a more highly skilled person.

The advent of computerized scheduling tools and even of general analytical tools such as spreadsheets has changed the nature of scheduling departments. These systems tend to allow more interaction among the traditional scheduling processes (schedule writing, blocking, runcutting, and rostering), reducing the tendency for schedulers to focus on only one aspect of the process.

Our experience is that it is more difficult to achieve proficiency in building tightly constructed schedules than in other areas of scheduling. There is almost an infinite number of ways that **revenue service** can be scheduled, which means this proficiency takes much longer to learn and comes easier for people with a certain set of intellectual aptitudes.

revenue service

When a vehicle is in operation along a route and is available to the public.

Scheduling Data Sources

Historically, schedule data was collected by real people recording passenger and time information on pieces of paper. This “traffic checking force” was a critical building block in scheduling. Now,many systems use their traffic checkers primarily to gather data for federally mandated reports (such as the National Transit Database) that are of little or no use by scheduling staff. Therefore, traffic checkers may report to a service planning section rather than to the scheduling department.

point checks

A technique to collect information about passenger loads and schedule adherence at a single location (or point), typically a time point or a location where branches of a route diverge. Also known as "line check."

ride checks

A technique to collect information about boarding and alighting at every stop, in addition to passenger loads and schedule adherence at all time points. Ride checks may also include data collection on type of fare paid, stop announcements, or other information of interest to the agency. Ride checks are more labor-intensive than point checks, but provide more complete data for a given route.

maximum load point

The location along the route where the passenger load is greatest. The maximum load point can differ by direction and by time of day. Long or complex routes may have multiple maximum load points, one for each segment.

block number

A unique number associated with a specific block, used to track the block throughout the scheduling process and as a means of identification for the operations department.

Data collection for scheduling can be conducted using traffic checkers, APCs, or AVL systems. Human checkers are still needed for special checks, e.g., at special events (concerts, sporting venues) and on rail systems where per-car loadings are required.

Two types of traffic checks are specific to scheduling and are vital for obtaining the information necessary for adjusting an existing schedule or building a new schedule. These are generally referred to as "**point checks**" and "**ride checks**."

Note that even for data collection with human checkers, the use of technologies is an integral part of the process. Almost all counts use spreadsheet or database systems for production of checker sheets, data entry, and analysis. Handheld devices can be used to undertake the actual collection, with a range of obvious benefits.

Point Checks

These are the simplest and take the fewest number of people to perform. They are most applicable for schedules that are demand-driven, rather than policy-based. A checker is stationed at a point on the route that is known to be the place where the greatest number of people are consistently on board. This point is known as the **maximum load point** or MLP for short. The checker records the number of passengers on board the bus either arriving at the stop, leaving the stop, or both, along with the arrival and/or departure time. Other identifying information, such as the bus number and **block number**[2] are recorded. General information about conditions is also noted, such as the weather and any unusual traffic conditions.

Point checks may also take on the nature of a spot check where unusual conditions occur, such as boardings at schools at a particular time of day. These are short in duration, just covering the times when boardings are the highest. They may be made by scheduling personnel who need the information quickly to correct a capacity problem. Besides the MLP, point checks may be regularly made at other points along the route, such as where branches diverge (or just beyond the point of divergence), or where short turns are scheduled. This gives vital information about the split of ridership along each branch. It is possible to obtain running time information by staging checkers at each time point and comparing their times, but it is vital that all checkers synchronize their watches so the information coordinates correctly.

On the subject of time, it is highly advisable to record both arrival and departure times, preferably required to the half minute (handheld devices allow recording to the second). The reason for this interest in half minutes (not that many systems still write schedules to this tolerance) is to provide greater accuracy in compiling running time information. End-to-end running times are generally rounded to the whole minute, but the half minute can make a difference when allocating times between time points.

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[2] At some systems, buses display run numbers instead of block numbers in their windshields.

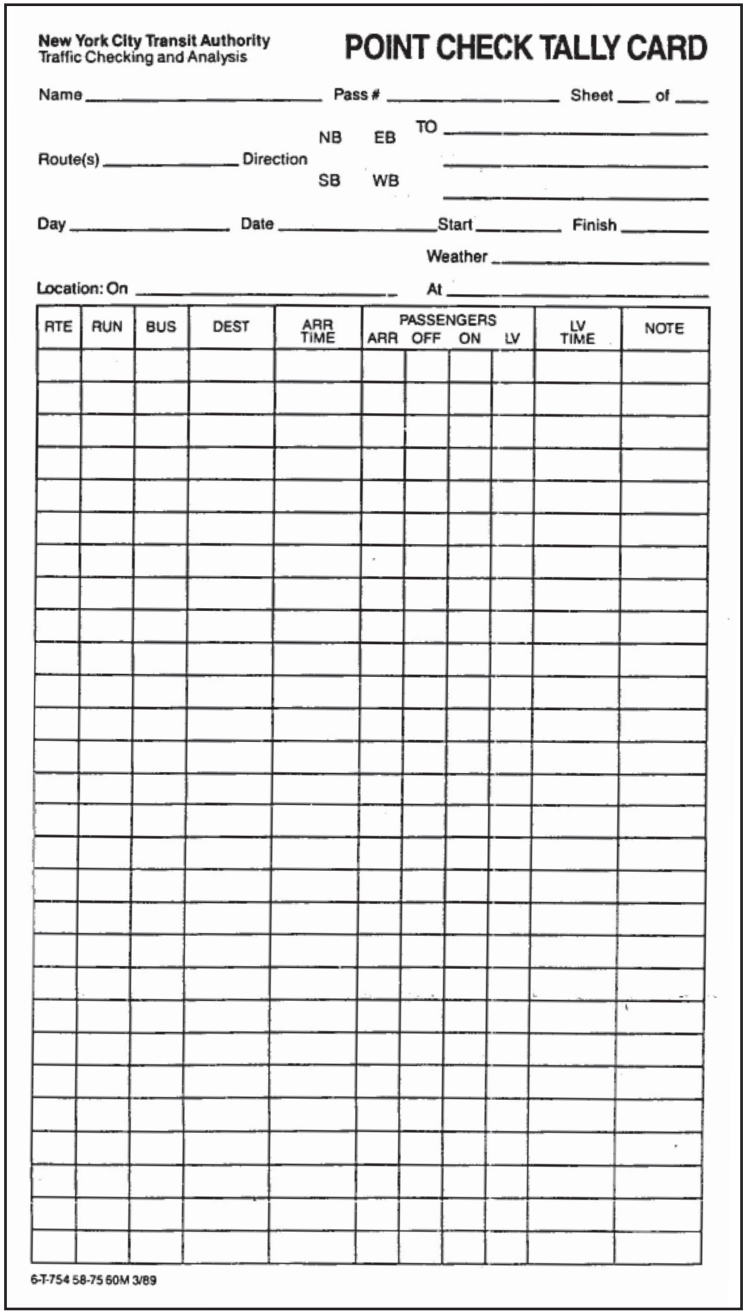
Bear in mind that one day of data may not be sufficient on which to base a schedule adjustment. There are too many variables in the operating day to be able to rely on one check as a good "average" of how the route operates regularly. Schedulers are constantly trying to construct the average schedule for the average passenger loadings operating in average street conditions and weather through average traffic. Since we know that the average day does not really exist, it is important to have enough checks to be able to distill down to that average. We hope we have made that point!

So, how many checks would yield a good representative of average conditions on a route? Those of us who began in the pre-computer days were taught to get counts on three days and compare them. Did they look similar? If so, take an **average weekday**. If not, throw out the outlier (i.e., the significantly dissimilar observation). Today, with greater data availability, the answer is really a function of the variability in loading and operation from day to day. Each route will have its own variability in these factors. By taking a few samples over time, use of sampling methodologies can easily be applied to identify confidence level estimates for this variation. Farebox data can provide a good basis for estimating sample requirements—simply measure the variability of ridership across days at whatever level of aggregation is required (daily, time period, or even trip level). This can tell you how big a sample is required.

The following is an example of a point check. These should be developed in a spreadsheet or database, which is also then used as the basis for data entry and analysis. This ensures consistency and improves accuracy.

average weekday

A representative weekday in the operation of the transit system computed as the mathematical average of data for several typical weekdays. A typical weekday is one where there are no anomalies such as high ridership due to extra service added for a special event or low ridership due to inclement weather. Some schedulers claim that this does not really exist. Average Saturday and average Sunday are determined in the same way.



New York City Transit Authority
Traffic Checking and Analysis

POINT CHECK TALLY CARD

Name ____________ Pass # ____________ Sheet ___ of ___

Route(s) ____________ Direction NB EB SB WB TO ____________

Day ____________ Date ____________ Start ________ Finish ________

Weather ____________

Location: On ____________ At ____________

RTE	RUN	BUS	DEST	ARR TIME	PASSENGERS				LV TIME	NOTE
					ARR	OFF	ON	LV		

6-T-754 58-75 60M 3/89

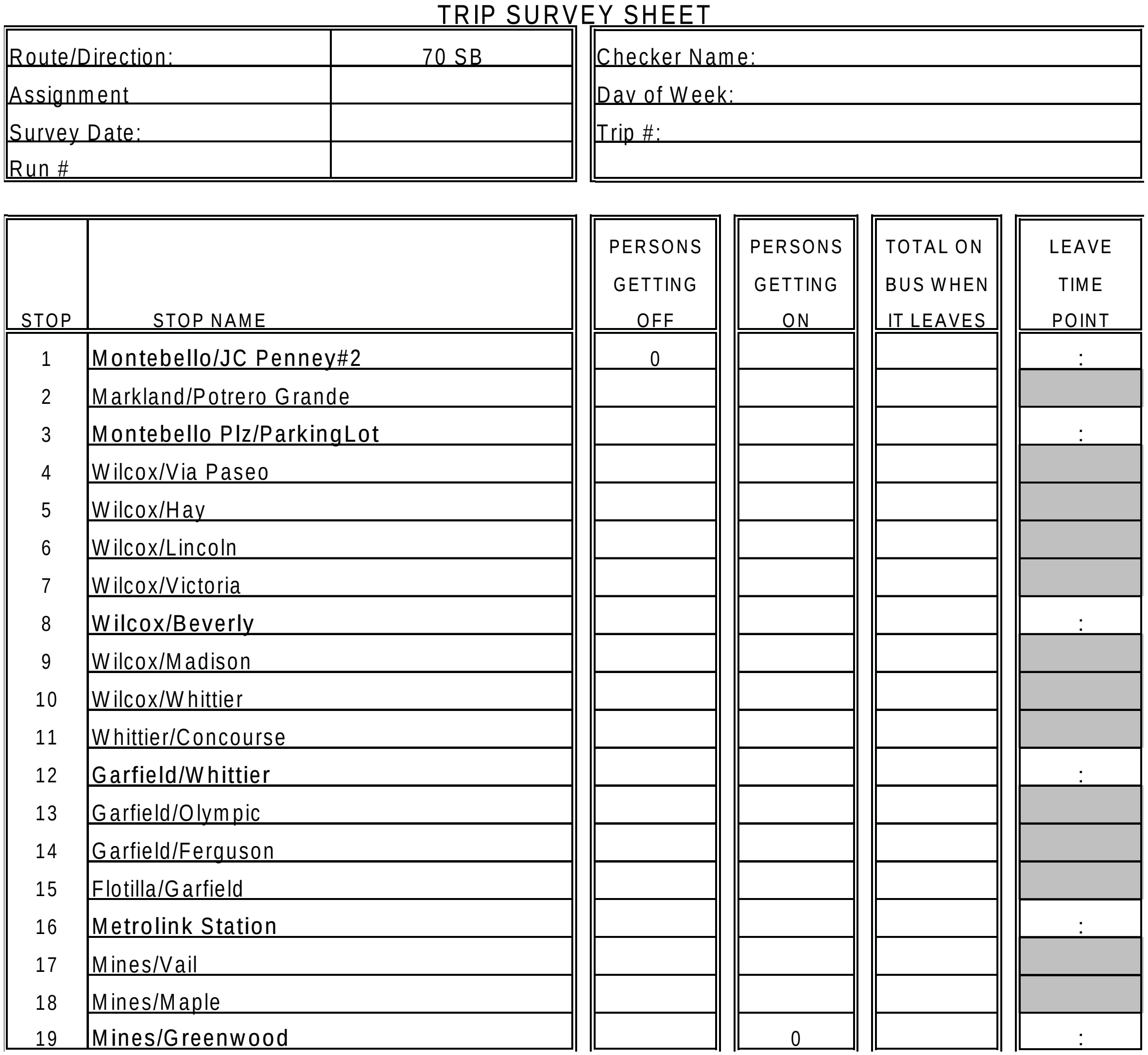
On-Board Ride Checks

If point checks seem to be so ideal, why do anything else? Point checks generate only a subset of the information needed to undertake many scheduling tasks. Their key benefit is that they collect a good deal of what is required with minimal manpower. One of their greatest deficiencies is they do not tell the scheduler anything about what is happening at other points along the route, but only provide a snapshot of what is happening at one location.

A far better solution is to collect full data for each trip through an on-board ride check. This is also more appropriate for policy headway routes, where patronage is lighter. It requires more resources but results in a more complete data set, providing the scheduler more information to make informed schedule adjustments. The systems that regularly perform ride checks tend to have, proportionate to their size, a far larger checking staff.

Again the issue of sample size needs to be addressed for the ride check. In this case the sample size relates to what percentage of trips on a given day are included (whereas for point counts the question was how many days). A particular point needs to be made here that you preferably check the entire day and not try to do half the trips one day and the rest on another. Days are unique. Loads are different. Operating irregularities are different. Two partial days of ride checks blended together may either accentuate problems or under emphasize them, but the blend does not always give you a representative look at the route.

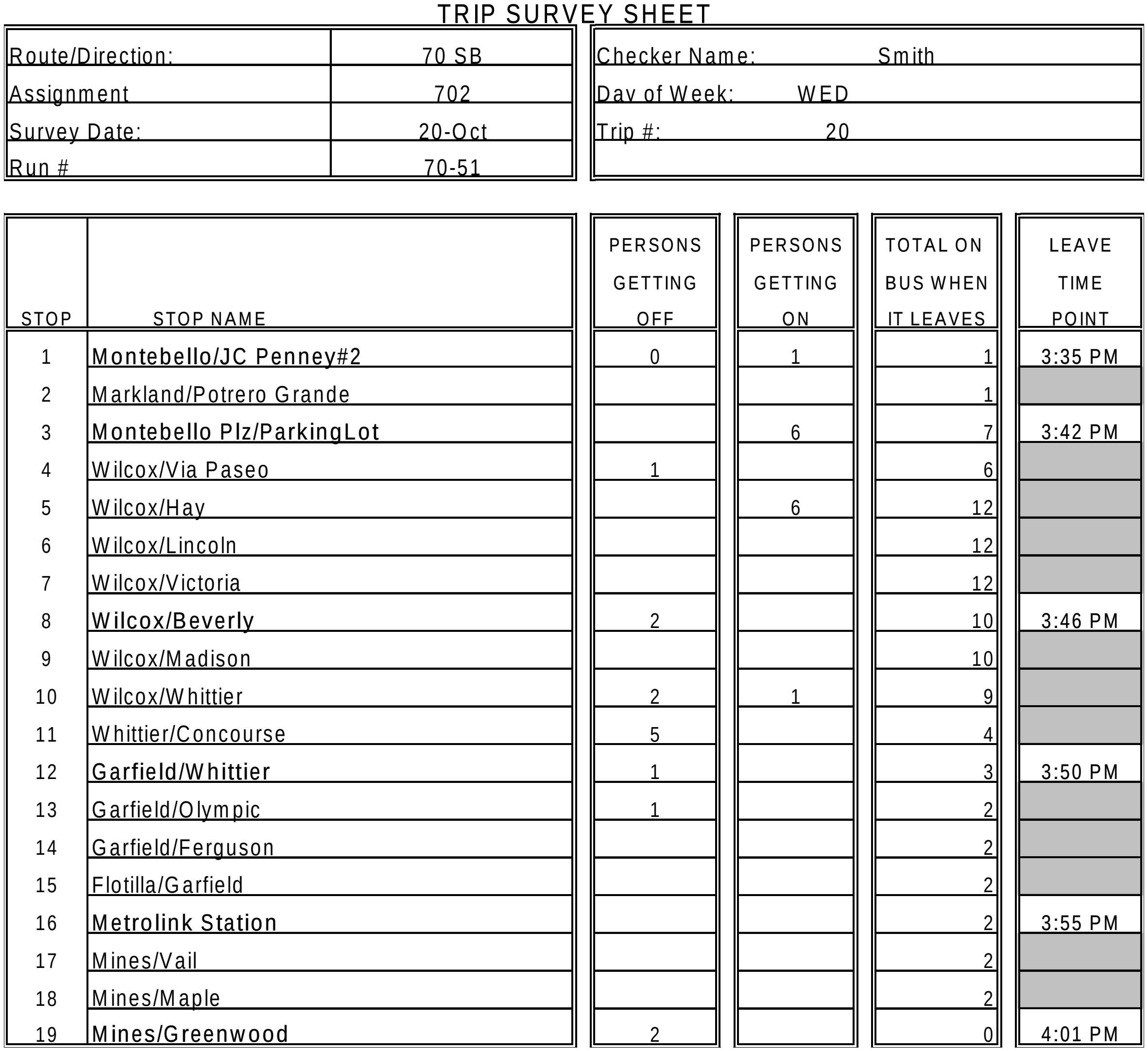
On-board ride checks are tabulated on forms which list all stops from end to end and provide columns for showing scheduled time and time points, for writing in the actual times and for noting comments about drivers' performance in operating over the route. These comments could address speed, unexpected stops/delays, and other aspects of interest to the agency. In addition, there are columns for recording boardings and alightings at each stop and carrying a running total of how many passengers are on board throughout the trip.



TRIP SURVEY SHEET

Route/Direction:	70 SB	Checker Name:
Assignment		Day of Week:
Survey Date:		Trip #:
Run #		

STOP	STOP NAME	PERSONS GETTING OFF	PERSONS GETTING ON	TOTAL ON BUS WHEN IT LEAVES	LEAVE TIME POINT
1	**Montebello/JC Penney#2**	0			:
2	Markland/Potrero Grande				
3	**Montebello Plz/ParkingLot**				:
4	Wilcox/Via Paseo				
5	Wilcox/Hay				
6	Wilcox/Lincoln				
7	Wilcox/Victoria				
8	**Wilcox/Beverly**				:
9	Wilcox/Madison				
10	Wilcox/Whittier				
11	Whittier/Concourse				
12	**Garfield/Whittier**				:
13	Garfield/Olympic				
14	Garfield/Ferguson				
15	Flotilla/Garfield				
16	**Metrolink Station**				:
17	Mines/Vail				
18	Mines/Maple				
19	**Mines/Greenwood**		0		:



TRIP SURVEY SHEET

Route/Direction:	70 SB	Checker Name:	Smith
Assignment	702	Day of Week:	WED
Survey Date:	20-Oct	Trip #:	20
Run #	70-51		

STOP	STOP NAME	PERSONS GETTING OFF	PERSONS GETTING ON	TOTAL ON BUS WHEN IT LEAVES	LEAVE TIME POINT
1	**Montebello/JC Penney#2**	0	1	1	3:35 PM
2	Markland/Potrero Grande			1	▨
3	**Montebello Plz/ParkingLot**		6	7	3:42 PM
4	Wilcox/Via Paseo	1		6	▨
5	Wilcox/Hay		6	12	▨
6	Wilcox/Lincoln			12	▨
7	Wilcox/Victoria			12	▨
8	**Wilcox/Beverly**	2		10	3:46 PM
9	Wilcox/Madison			10	▨
10	Wilcox/Whittier	2	1	9	▨
11	Whittier/Concourse	5		4	▨
12	**Garfield/Whittier**	1		3	3:50 PM
13	Garfield/Olympic	1		2	▨
14	Garfield/Ferguson			2	▨
15	Flotilla/Garfield			2	▨
16	**Metrolink Station**			2	3:55 PM
17	Mines/Vail			2	▨
18	Mines/Maple			2	▨
19	**Mines/Greenwood**	2		0	4:01 PM

automatic passenger counting (APC)

APC systems count the number of boardings and alightings at each stop while also noting time, location, and direction. Infrared beams are the most common means used in counting. Stop location is identified through the use of data sources such as global positioning systems (GPS), signpost emitters, GIS maps, odometer readings, and inertial navigation. Data from all these sources must be extensively compiled (from multiple buses/trips on a route) and processed, either by an on-board computer or centrally, to be meaningful.

automatic vehicle location (AVL)

AVL systems are vehicle tracking systems that function by measuring the real-time position of each vehicle and relaying this information back to a central location. The vehicle location is identified through the use of global positioning systems (GPS). The information is used to assist transit dispatchers as well as inform travelers of bus status. AVL is a potential source of running time and on time performance data for scheduling, but only if an archival reporting system is included.

Some days or seasons are more or less ideal for collecting representative data. This will vary by system, weather, and the importance of school ridership in the overall operation. When school is a factor, in-session times when classes are stable give the most accurate picture for school time service level requirements. These are usually the months of March, April, October, and November. Those are also the best when weather is a big factor. Days of the week differ as well. Mondays and Fridays are not ideal checking days, as loads tend to be lower on those days, and traffic on Fridays is different from other weekdays. Obviously, days before and after holidays are not typical weekdays either.

APC and AVL Systems

APCs provide an automated version of on-board ride checks. The APC will collect time, location, and passenger boarding/alighting information, much in the way an on-board survey does. The obvious benefit of APCs is the capacity to generate many days of data for as many routes as the number of APC units will permit. The difficulties are in initial calibration of the systems, in daily vehicle assignment (if only a portion of all vehicles are equipped with APCs), and in staff's ability to analyze the sheer volume of data produced.

The latter problem is a good one as far as scheduling is concerned. Schedulers work well with a wealth of data. Two common elements contributing to successful implementation of APCs are a sound validation program to flag data of questionable quality and good reporting capabilities. The latter can include standard reports to provide schedulers with the information they need most often (boardings, alightings, loads and time by stop, and running time by segment) and the flexibility to create ad-hoc reports to query the APC database as needed.

AVL systems track vehicle location throughout the day, but do not collect ridership data. Thus, the primary use of AVL data for scheduling is in the evaluation of schedule adherence and running time analysis. As with APCs, data validation and reporting capabilities enhance the reliability and usefulness of AVL data. Agencies that use both APCs and AVL tend to rely on the AVL system for time-related data.

As more and more transit agencies acquire APC and AVL capabilities, either as stand-alone systems or as part of a broader Intelligent Transportation Systems procurement, schedulers will have more and better quality data at their disposal. APC and AVL will largely replace human checkers but, as noted earlier, there are instances where human checkers are still needed (for example, cross-checking APC and AVL systems on buses not equipped with APC). A final point is that automated data collection can tell you what is happening but cannot tell you why. Observations from operations personnel and fieldwork by the schedulers will remain an important part of the scheduling process.

We mentioned at the beginning that there were other types of checks that were less useful for schedulers. To complete our picture of data accumulation methods, we list these here:

- Trail checks entail following buses in a car over specific segments of a route. They can be useful for looking at general operations along a segment of route that is being studied for rerouting or discontinuation, but are not the preferred method for obtaining boarding, alighting, or running time data.
- Farebox counts do give a record of how many patrons boarded on each trip (if the driver has been diligent to reset the box at the start of each trip), but they do not tell where passengers got on or off the bus. More importantly, fareboxes cannot tell the maximum number of passengers on board for each trip. Farebox counts are useful for identifying ridership trends.
- Cordon counts are a common means in traffic engineering to count vehicles and people entering and leaving a specific area, typically a city center. Some of this information at a specific corridor level may be of interest to transit, but overall results are of little use for scheduling purposes.

Chapter 3.
Schedule Building

span of service

The length of time, from the beginning of the first trip to the end of the last trip, during which service operates on the street. Can be expressed for a route or for the system as a whole.

headway

The interval of time between two vehicles running in the same direction on the same route, usually expressed in minutes. See also "frequency."

service pattern

The unique sequence of stops associated with each type of trip on a route. If all trips operate from one end to the other on a common path the route has one service pattern. Branches, deviations, or short turns introduce additional service patterns. Service patterns are a fundamental component of scheduling and provide the framework for tracking running time, generating revenue trips, and identifying deadhead movements for the route.

deadhead

The time and distance that a bus needs to travel in places where it will not pick up passengers. Deadheading is typically required to get buses to and from their garage, or need to travel from one route or point to another during their scheduled work day.

3.1 Building a Simple Schedule

LEVEL 1

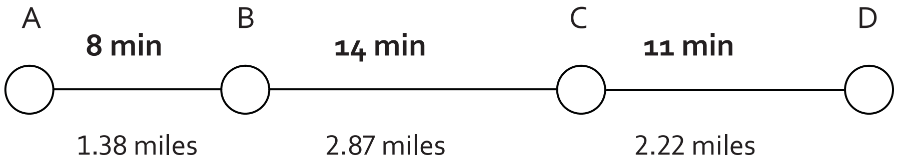
Even a simple schedule reveals some important concepts that apply in one way or another to all scheduling. In fact, the most complicated schedule is no more than a series of the same steps we will talk about here.

Do not be misled by our calling this a "simple" schedule. Sometimes the most difficult schedules are those with the fewest options (i.e., the "simple" ones!). In reality, scheduling only becomes simple by doing it over and over again.

For this project we will build a straightforward 30-minute all-day schedule on a single route that operates just one service pattern. Let's call this Route 97—Broad St.—a new route being developed. We are just interested in the weekday schedule for now.

Here is what you need to know:

- **Span of Service** – 6:00 AM to 7:00 PM
- **Headway** – 30 minutes throughout
- **Service patterns** – All trips operated from time point A to time point D. Reverse direction trips from D to A
- **Garage** – This route operates out of Park Garage which is nearer to the time point A end of the route
- **Deadhead times** to and from the garage are: 10 minutes to/from "A," 20 minutes to/from "D"
- **Mileage and running time** – shown in the diagram below



The upper numbers are minutes between time points, the lower is the mileage.

Most of this information will come from a service plan or from discussion with planners. It will always be up to you to verify this information, because ultimately the responsibility for the development of the operating schedule falls to you.

So, where to start? Here is the general sequence of events:

1. Calculate the round-trip **cycle time**, including layover.
2. Figure out how much layover you have and where to apply it.
3. Work out the basic **schedule pattern**. This is the key to the task and includes consideration of:
    - The cycle and **layover times**
    - Contract layover requirements
    - Operational preferences
    - Runcut requirements
4. Decide where and when (based on the span of service standard discussed in Chapter 2) to start service.
5. Populate the schedule.
6. Then, and only then, fill in the intermediate times, working downward while constantly checking adjacent running times.
7. Block your schedule by following the first trip and its subsequent trips (hooks) all the way to the end of the schedule, then filling in the rest of the block numbers in the same manner. This and subsequent steps are addressed in Chapter 4: Schedule Blocking.
8. Mark your **pull-on** and **pull-off** locations for each block, and apply the out or in time to and from the garage.
9. Build a table of your blocks, showing **pull-out** and **pull-in** times and resulting vehicle hours. The table will add up at the bottom to the total vehicle hours for the schedule.
10. Build a table of mileage along the same principle, yielding total mileage for the schedule.
11. Proofread your work before declaring the schedule finished and ready for the runcut.
12. If need be, hand the schedule back to the planning staff so they can see what their concept looks like when turned into reality.

Let's tackle steps one through six, which are most integral in building a schedule. Steps seven through 12 are discussed separately in Chapter 4: Schedule Blocking.

cycle time

Sum of the round-trip running time plus layover time. Also known as "round trip cycle time."

schedule pattern

A summary of the schedule in terms of running times between time points and layover time at terminals. The schedule pattern can be repeated throughout the day or can change as running times and layover times change during the day.

layover time

Time between the scheduled arrival and departure of a vehicle at a transit terminal. Often used interchangeably with "recovery time," although technically layover time is rest time for the operator between trips while recovery time is time built into the schedule to ensure an on-time departure for the next trip. In this manual, layover and recovery are calculated together and the total time between trips is referred to as "layover."

pull-on location

The place on a route where a vehicle begins revenue service.

pull-off location

The place on a route where a vehicle ends revenue service.

pull-out time

The time the vehicle spends traveling from the garage to the route. Pull-out time is included in vehicle hours, but not in revenue hours. Collectively, pull-in time and pull-out time are also known as pull time and are components of deadhead miles.

pull-in time

The time the vehicle spends traveling from the route to the garage. Pull-in time is included in vehicle hours, but not in revenue hours. Collectively, pull-in time and pull-out time are also known as pull time and are components of deadhead time.

1 Round-trip Cycle Time

This is the most important concept you will master in building a proper schedule. The round-trip cycle time is:

Round-trip running time + required layover

Since the round-trip running time must be already calculated and accurate, it is crucial to this formula. On routes where running times vary by time of day, this cycle must be calculated for different times of the day. This example uses the information we have been given for Route 97. Working across the diagram on page 3-1 from left to right (we will call this eastbound) we find running of 8, 14 and 11 minutes, which add up to 33 minutes. The same 33 minutes apply westbound. This gives us a 66-minute round-trip. To that, an adequate layover must be added.

2 Layover Requirements

Layover requirements will be explored in greater detail in the following sections. For now, we will assume some basic principles. Possibly your union contract specifies a minimum layover either at one end of the route or for a full round-trip. If the union contract does not address layover, past practice may guide the allocation of layover time. An example of minimum layover is 10% of the running time or six minutes per round-trip, whichever is greater. This route might need more than that, depending on propensity for traffic congestion, a high number of wheelchair boardings, and other operational details that cannot be accurately predicted in the running time. If so, then you will want to add some minutes to that required by the contract or allocated by past practice.

In our example, 10% of 66 would be seven minutes (always round up to the next minute if the percentage is a minimum)—which, added to the running time, would give us a round-trip cycle of 73 minutes. That is the minimum cycle we can operate.

Now the tough part comes in. We have to divide the cycle by the intended headway for the period. In this case, we have a requirement for a 30-minute headway all day. Multiples of 30 are 30, 60, 90, 120, etc. We just missed 60 and we cannot squeeze the running time back to fit into that cycle. Reducing layover below the minimum or reducing running time below the calculated requirement is taboo, especially once we have determined that we need every bit of the 66 minutes. So we have to see what other options we have.

Since the cycle time cannot be shortened, one option would be to extend the round-trip cycle to 90 minutes, the next highest 30-minute multiple, requiring 3 buses (90 divided by 30). That would give us a total of 24 minutes of layover, or 36%—a wasteful amount, with the bus and its operator sitting idle one third of the time. But if we have a system set up on pulses at a **transit center** or other meet point, this may be our only option. In fact, if we generally allow five minutes of connection time in each direction at a mid-route transit center, this allowance would bring us back to 14 minutes that would be available for end of line layover, or 20%—a more reasonable number.

Another option is to look at a better service level. If we stay to a clockface headway, a 20-minute headway would be our next choice. Progressions of 20 are 20, 40, 60, 80, 100, etc. An 80-minute cycle would provide 14 minutes of layover and a better frequency, but it would require one more bus to operate the schedule (80 divided by 20). Can we afford the extra all day bus? An extra bus translates to about 13 extra bus hours for the day, every day. Would a 20-minute headway work in any connection strategy we might have? Finally, do we really need a 20-minute headway in order to carry the expected ridership levels? If the answer to any of these questions is "no," then this is not our option.

One final option is to look at a non-clockface headway. In this case, a 25-minute headway with three buses would give us a 75-minute cycle, which is just three minutes more than our so-called minimum cycle, which is just fine if we can tolerate a 25-minute headway. The resulting schedule is not easy to remember, but in this case it does have the advantage of providing two extra round-trips during the operating day for the same number of buses and bus hours. While clockface headways are nice, the reality is that most people will consult a **timetable** for any service that is less frequent than every 15 minutes.

One other possibility exists—which is to use the extra time available to extend the route and increase coverage. This kind of route adjustment to fit the schedule is usually done when initially planning and scheduling the route or when considering a route extension. This is a good example of why there has to be a working collaboration process between planners and schedulers. Route design should always seek to take advantage of scheduling efficiencies and, more importantly, avoid creating inefficiencies.

Since our schedule is a simple one, with the same headway and running time all day, we only need to calculate one round-trip cycle and make one determination as to where to apply the layover. This strategy will work all day. We will see examples of schedules with lots of variations in the intermediate and advanced sections later in this chapter.

Tip Never reduce a minimum required layover time or calculated running time to "squeeze" the cycle to better fit the headway.

transit center

An area designed to be served by multiple routes. A transit center may be on-street or off-street, but in either case stop locations are established to facilitate passenger connections and safe vehicle movement. In radial networks, transit centers were located in downtown areas. With the emergence of hub-and-spoke networks, an agency may utilize multiple transit centers (or hubs).

timetable

A document containing route and time information produced for use by riders.

Tip Time point placement is important. You do not want these points too close together nor too far apart. They should be at major intersections or other major points along the route, as the public will look for exact times at these points on the printed timetable. A rule of thumb is that time points are ideally spaced between about 7 and 15 minutes apart, or an average of about 10 minutes between each one. Beyond the need to inform the public of scheduled arrival times, time points serve to help drivers "pace themselves" when driving the route. The scheduler should also ensure that bus stops exist in both directions at a time point, to avoid confusing the riding public.

In this example, we have decided on the 30-minute headway using three buses. The excess layover time is not desirable, but works to our advantage for a route that connects with other routes in our system at a mid-route timed transfer point. We will discuss timed transfer schemes in a later section.

3 Basic Schedule Pattern

Most basic schedules are laid out either using spreadsheets or computerized systems. For this exercise we will assume a spreadsheet is being used.

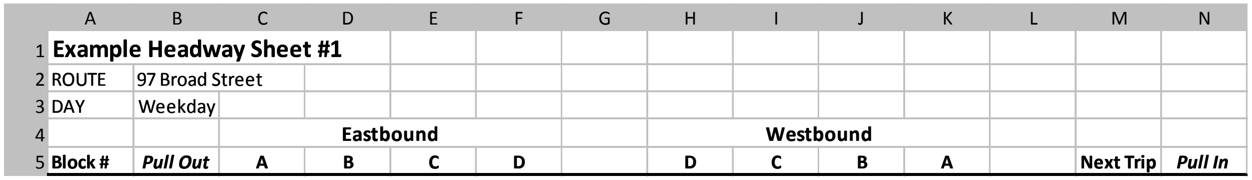
There are some important issues to consider about spreadsheet design. These include:

- *Simplicity.* Avoid getting too complex with presentation. Use basic colors.
- *Location of inputs and outputs.* Think about who will look at the sheet, and how it will be used. Should fixed inputs (running times, mileage, etc.) be hidden to the side, on a separate sheet, or readily visible?
- *Use of formulas.* We will state repeatedly throughout this manual the importance of accuracy. Spreadsheets are terrific tools for minimizing repetitive work. They also present pitfalls, as errors can be difficult to find and/or trace. The key principle in design of a headway sheet should be to use formulas as much as possible—if you can avoid typing a number that can be calculated, do so!

  Why? There are two main reasons. First, the need to avoid errors, which are more likely to occur through manually typing numbers. Secondly, schedules inevitably change (you will see an example shortly). The more automated a sheet is, the easier (and less prone to error) the change process will be. If you want to highlight things, consider use of conditional formatting. As you will see on the sample spreadsheet, there are only two typed values. The rest are formulas.

In laying out the schedule, it is a lot easier to have the two directions placed side by side. You can see the flow of the schedule better that way, although it does take some prior planning on how you lay out the sheet.

Start preparing the headway sheet or **master schedule** by naming the columns across the top. Start with the Eastbound direction first (that is our preference, but it can work to start with westbound first if you have a compelling reason to do so…or just favor doing it that way). Column A is for the **block** number. Here is where we will keep track of the bus rotation in the schedule. Column B is for Pull-Out times or the time the bus leaves the garage. Columns C through F are time points by name, in our case A, B, C, and D. Leave Column G blank and start back westbound with time points D, C, B, and A. Then leave Column L blank and label Column M Next Trip. Column M is where you will keep track of **hooking round-trips** to their next trips or, when running out of trips, will indicate by a blank that they become a pull-in. Follow that with Column N for Pull-in. Your spreadsheet will look like this:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Example Headway Sheet #1**													
2	ROUTE	97 Broad Street												
3	DAY	Weekday												
4			**Eastbound**					**Westbound**						
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	***Pull In***

A quick note about the term "block." This is the term for the vehicle (bus, light rail vehicle or train, heavy rail train, etc.) assignment, which describes what the vehicle will do in a day. Some systems call this a "train" or a "run" or even a "key." We use "block" because that is the prevailing term in the industry and is less likely to be confused with "run," which is predominantly applied to the driver, not the vehicle, assignment.

master schedule

A document that displays all time points and trips on a route. Usually includes run numbers, block numbers, and pull-in and pull-out times. Used interchangeably in this manual with "headway sheet."

block

A vehicle (or train) assignment that includes the series of trips operated by each vehicle from the time it pulls out to the time it pulls in. A complete block includes a pull-out trip from the garage followed by one or (usually) more revenue trips and concluding with a pull-in trip back to the garage.

hooking

The process of attaching the end of a trip in one direction to the beginning of a trip the other direction. A block is a series of hooked trips.

round-trip

A trip that travels along a route and then returns to its original starting point; a combination of two one-way trips on a route.

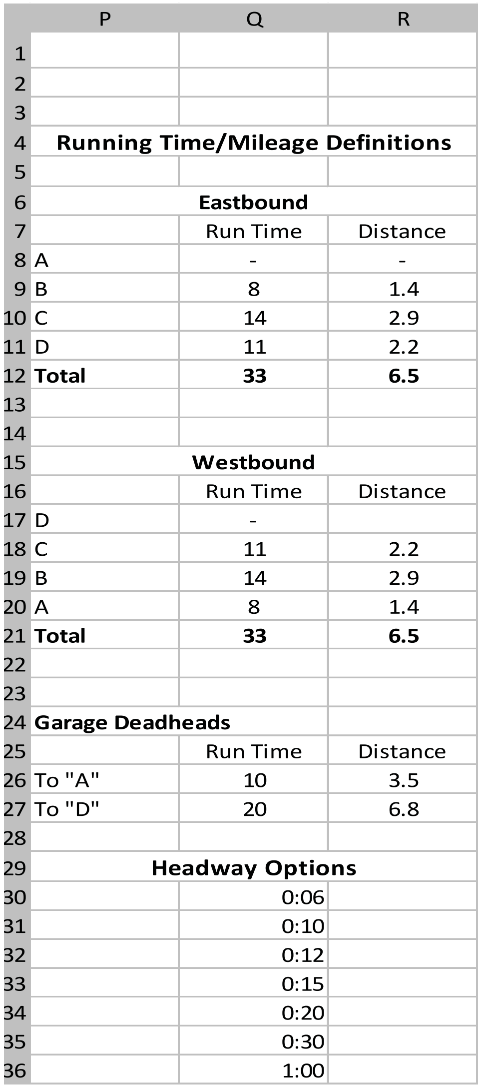
Tip Note that we enter various clock face headway options in time format in cells Q30:Q36. These will remain the same no matter how many times we use this spreadsheet, and the time format saves a step in entering formulas, as we will see below. Running times are subject to change, and so it is simpler to enter them in general format.

We start by noting down some basic information—the running time and distance between time points in each direction and the headway, for starters. We will put this out of the way, to the right of the schedule, in columns P through R, as shown here. We also add in time and mileage from the garage to the two end points of the route.

Before we start writing in trip times, we take a step backwards—to the answer! One of the key tenets of scheduling is to know the answer before you jump into the detail. In this case, looking at a few simple calculations (as we did above), we can see how everything will pan out before we write any schedules.

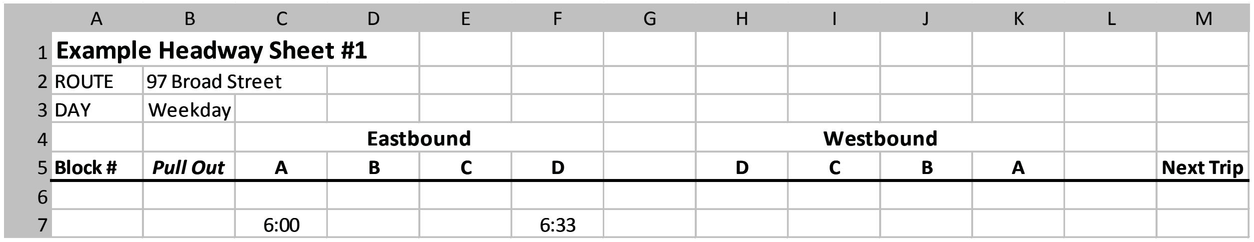
The key to this is the development of a schedule pattern. This concept can be applied to the simplest schedules as effectively as it can be applied to a 10-route interline with complex branching patterns.

The schedule pattern in effect summarizes the schedule, for all or part of a day. In this case, since the running time and headway is constant, the schedule pattern will summarize operation for the entire day.



	P	Q	R
1			
2			
3			
4	**Running Time/Mileage Definitions**		
5			
6	**Eastbound**		
7		Run Time	Distance
8	A	-	-
9	B	8	1.4
10	C	14	2.9
11	D	11	2.2
12	**Total**	**33**	**6.5**
13			
14			
15	**Westbound**		
16		Run Time	Distance
17	D	-	
18	C	11	2.2
19	B	14	2.9
20	A	8	1.4
21	**Total**	**33**	**6.5**
22			
23			
24	**Garage Deadheads**		
25		Run Time	Distance
26	To "A"	10	3.5
27	To "D"	20	6.8
28			
29	**Headway Options**		
30		0:06	
31		0:10	
32		0:12	
33		0:15	
34		0:20	
35		0:30	
36		1:00	

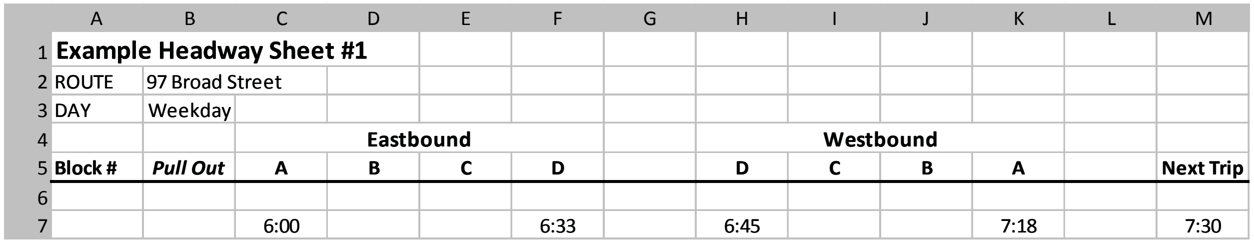
First, we enter a time for the first eastbound trip. We start with 6:00 and our schedule pattern sheet looks like this:



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Example Headway Sheet #1**												
2	ROUTE	97 Broad Street											
3	DAY	Weekday											
4			**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**
6													
7			6:00			6:33							

The arrival time at Point D, the end of the route, is a simple formula that takes the depart time cell and adds the running time (also defined in the spreadsheet). The formula can be entered in one of two ways: =C7+(0.00069444*Q12) or =C7+time(0,Q12,0).

We already have half the schedule pattern complete and are well on the way to creating our schedule. Next we look at the return trip. It needs to depart no earlier than 6:37 (based on the minimum 4-minute layover). We are now faced with making a decision as to where to apply our 24 minutes of layover time. We can apply it evenly—12 minutes at each end—or we can provide different layover times at each end. In real-world operations, there are concerns with laying over for too long at some locations, which would help make our decision. On some systems, it is standard practice to give no layover at the outer **terminal** and allow the buses to take their time at the downtown or transit center point on the route. Others without an off-street transit center downtown may give minimal layover downtown and allocate most of its layover time at the outer terminal. In this case, we will apply 12 minutes to each end of the route. That will give us leaving times from "D" at :15 and :45 past the hour. Having made that decision we update our schedule pattern to look like this:



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Example Headway Sheet #1**												
2	ROUTE	97 Broad Street											
3	DAY	Weekday											
4			**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**
6													
7			6:00			6:33		6:45			7:18		7:30

Tip The factor 0.00069444 converts a regularly formatted number to minutes in the time format. This factor is equivalent to 1/24/60. An alternate entry is TIME (x,y,z), where x is hours, y is minutes, and z is seconds. Using this, the equation in the second row under B would be "=C7 + TIME (0, Q12,0)."

terminal

One end point of a route where trips usually begin and end.

Guess what? The schedule is now effectively built! First we need to check a couple of things:

1. How many buses? If our bus arrives back at "A" at 7:18, and there are departures at :00 and :30, its next possible trip would be the 7:30 trip. Is that correct according to our plan? Yes—it produces a 12-minute layover at each end.

   So how many buses do we need? This becomes a simple calculation of dividing the cycle time (inclusive of scheduled layover) by the headway. In this case, 90 minutes (i.e., 7:30 minus 6:00) divided by the 30-minute headway is three—and there is our answer, three buses!
2. Are we happy with the times at the ends, and any key intermediate points?

We now have a schedule pattern that we simply begin at the start of the day and end when we want our service to end. And we know how many buses we need.

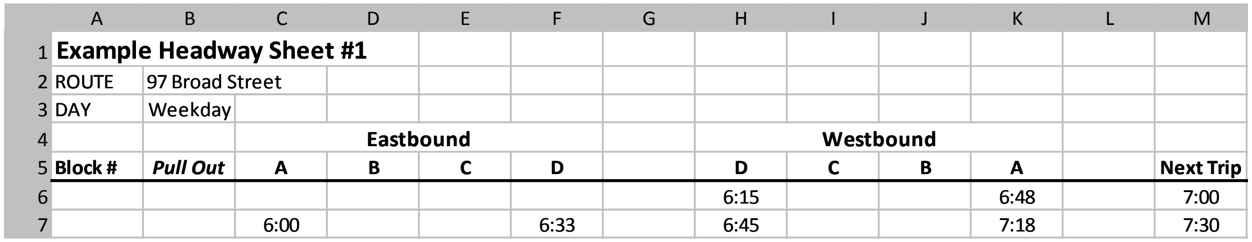
4 Decide When to Start Service

We still need to decide when the first trip should start in each direction. Our service plan says that service will operate from 6:00 AM to 7:00 PM. Does that mean that we must begin service in both directions at 6:00 AM?

It may be obvious to you who are mathematically inclined at this point that we cannot have a 6:00 AM leaving time at the "D" point once we have decided to leave from "A" on the hour and the half-hour. A 6:33 AM arrival at "A" would not have another trip until 7:00 AM, which would be too late in returning to "D" to make the 7:30 next trip. We would end up with four buses instead of three on this route.

So, what now? We are meeting the goals of the service plan by starting promptly at 6:00 AM eastbound. But our schedule pattern calls for the westbound trip to be either :15 or :45 past the hour. Is 6:15 early enough to meet the expected demand (or the intent of the service specification), or should we look at a first westbound trip at 5:45, one cycle earlier?

Knowing your system will help you answer that. The biggest question is whether there is general demand in your community for service at 6:00 AM or earlier. A lot also depends on expected ridership from the east end of the route as compared to the west end. More people might be expected to travel westbound earlier due to work or school demands. If so, then a 5:45 AM trip should be the first from that direction. From an efficiency standpoint, it will be cheaper to start the trips going east, since the garage is closer to that end of the line, but that is generally less important than making sure that the schedule serves the expected ridership. If this were a fixed guideway (light rail or trolley coach) route, then it would be necessary to start out trips earlier than necessary in one direction to assure they are in position to start the service **on time** in the other direction. In our case, we will make a decision based on the knowledge of our hypothetical system to have the first westbound trip leave point "D" at 6:15 AM. After adding this trip, your spreadsheet looks like this:

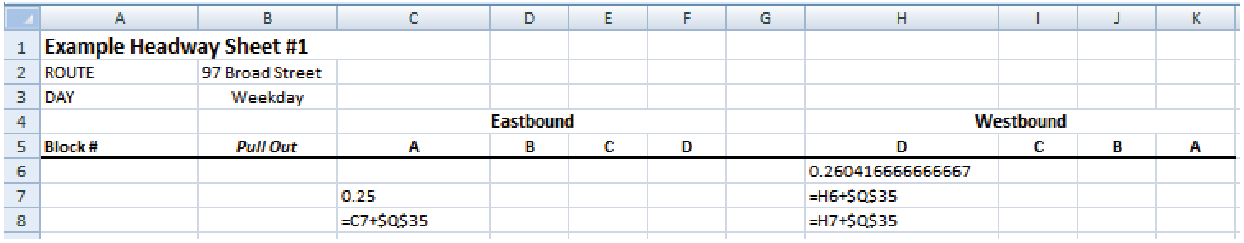


	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Example Headway Sheet #1**												
2	ROUTE	97 Broad Street											
3	DAY	Weekday											
4			**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**
6								6:15			6:48		7:00
7			6:00			6:33		6:45			7:18		7:30

One of the beauties of spreadsheets is that if you happened to enter the 6:00 eastbound trip in Row 6 instead of Row 7, you could simply insert a row to enter the westbound trip.

5 Populate the Schedule

The next step is filling out the schedule. Now that we have the basic schedule pattern and have decided on the starting time in both directions, we simply repeat the schedule pattern. So eastbound trips depart "A" at :00/:30, and westbound trips depart "D" at :15/:45. This is easiest to do with a formula, in which we add thirty minutes (the headway, which is located in cell Q35) to the previous trip. Row 8 would look like this, using the "show formula" feature:

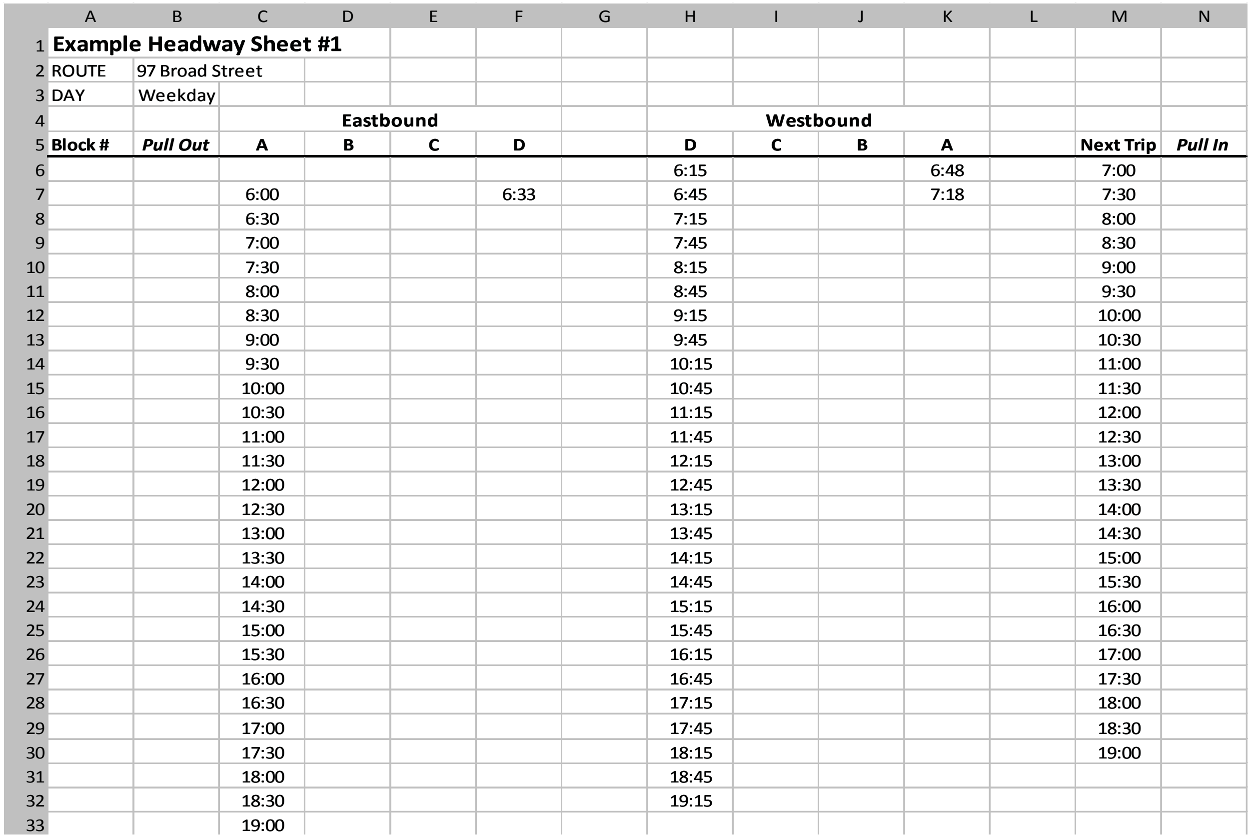


	A	B	C	D	E	F	G	H	I	J	K
1	**Example Headway Sheet #1**										
2	ROUTE	97 Broad Street									
3	DAY	Weekday									
4			**Eastbound**					**Westbound**			
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**
6								0.260416666666667			
7			0.25					=H6+$Q$35			
8			=C7+$Q$35					=H7+$Q$35			

on time

Defined specifically by each system, a trip is considered on time if it arrives or departs from a time point within a specified range of time. A typical range is 0 to 5 minutes after the scheduled arrival/departure time. A trip that leaves a time point early is referred to as "hot" or "running hot."

Then, after we copy the formula in row 8 down columns C and H (corresponding to the leave times at points A and D), we have the basic schedule populated throughout the day:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Example Headway Sheet #1**													
2	ROUTE	97 Broad Street												
3	DAY	Weekday												
4			**Eastbound**					**Westbound**						
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	***Pull In***
6								6:15			6:48		7:00	
7			6:00			6:33		6:45			7:18		7:30	
8			6:30					7:15					8:00	
9			7:00					7:45					8:30	
10			7:30					8:15					9:00	
11			8:00					8:45					9:30	
12			8:30					9:15					10:00	
13			9:00					9:45					10:30	
14			9:30					10:15					11:00	
15			10:00					10:45					11:30	
16			10:30					11:15					12:00	
17			11:00					11:45					12:30	
18			11:30					12:15					13:00	
19			12:00					12:45					13:30	
20			12:30					13:15					14:00	
21			13:00					13:45					14:30	
22			13:30					14:15					15:00	
23			14:00					14:45					15:30	
24			14:30					15:15					16:00	
25			15:00					15:45					16:30	
26			15:30					16:15					17:00	
27			16:00					16:45					17:30	
28			16:30					17:15					18:00	
29			17:00					17:45					18:30	
30			17:30					18:15					19:00	
31			18:00					18:45						
32			18:30					19:15						
33			19:00											

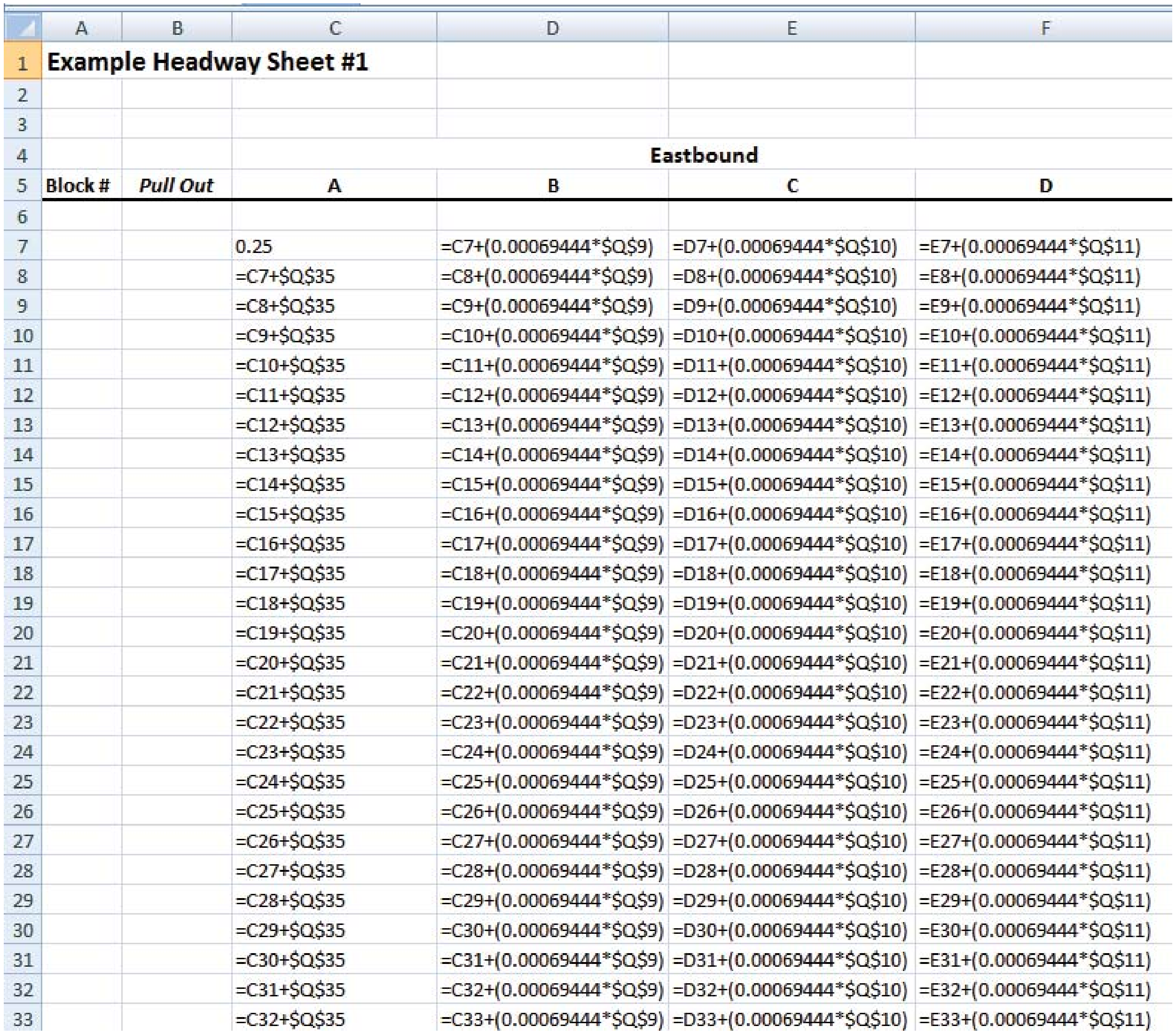
6 Fill in Intermediate Times

Now we can start writing trips. Using a spreadsheet this is a very simple process. Just create a depart time, and then use formulas (adding the appropriate running time minutes to the previous cell). Remember that we have entered running times between time points in cells P6:Q21. Cells Q9 through Q11 contain eastbound running times, while cells Q18 through Q20 contain westbound running times. Using the "show formula" feature of Excel, we enter the following formulas in Row 7 (eastbound) and Row 6 (westbound). For space purposes, eastbound and westbound are shown separately. In the westbound example, formulas in Row 6 have been copied to Row 7. The formula converts a regularly formatted number to minutes in the time format, as presented earlier.

Eastbound			
A	**B**	**C**	**D**
0.25	=C7+(0.00069444*$Q$9)	=D7+(0.00069444*$Q$10)	=E7+(0.00069444*$Q$11)

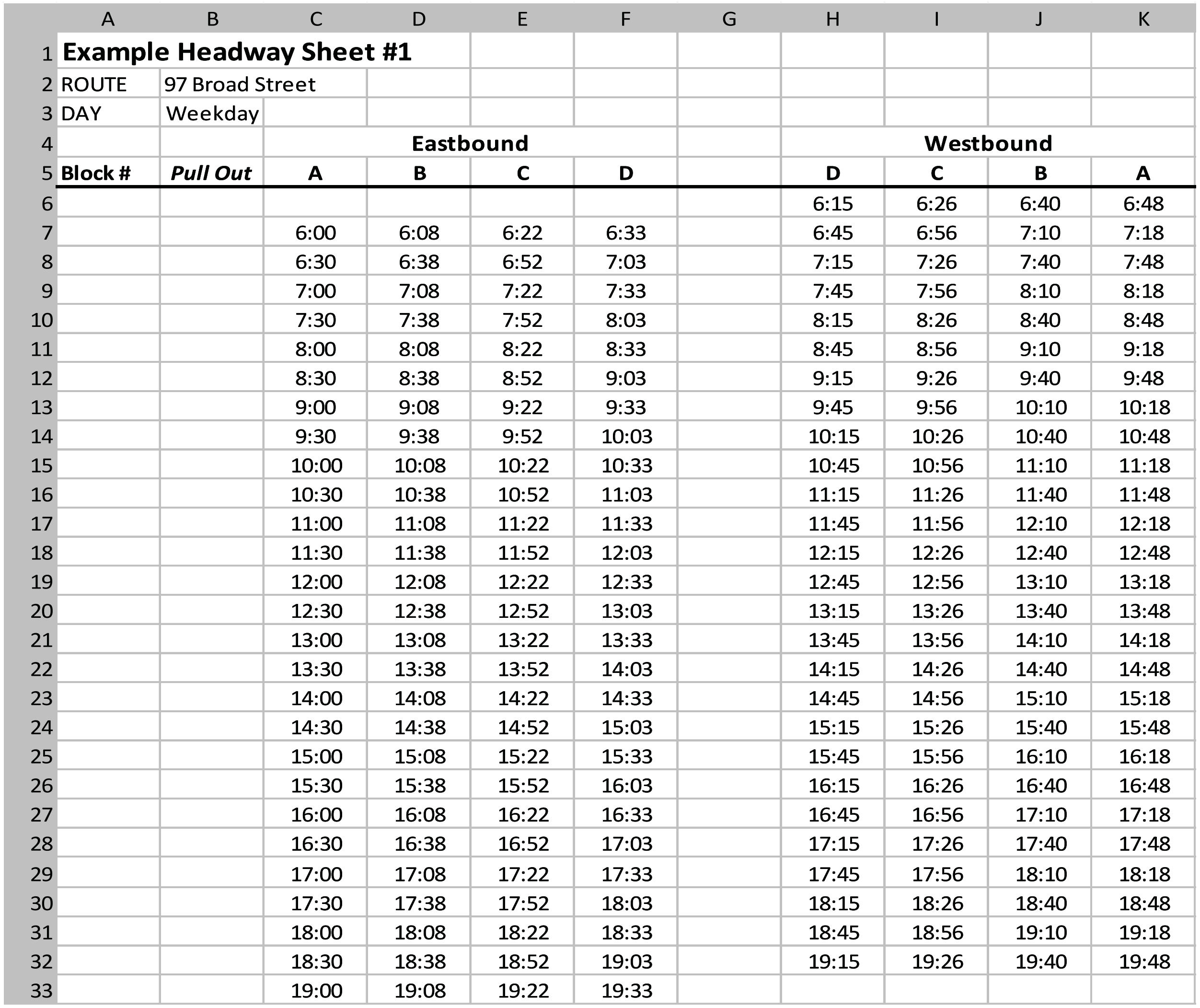
Westbound			
D	**C**	**B**	**A**
0.260416666666667	=H6+(0.00069444*$Q$18)	=I6+(0.00069444*$Q$19)	=J6+(0.00069444*$Q$20)
=H6+$Q$35	=H7+(0.00069444*$Q$18)	=I7+(0.00069444*$Q$19)	=J7+(0.00069444*$Q$20)

Formulas can also be used to add trips down the page, but it is easier to copy row 7 (cells D7: K7) down the page. In fact the whole schedule can be written with just two actual values—the first trip in each direction. The rest will flow as formulas. This allows ready manipulation of the trips and schedule, which is a key ally in a scheduler's arsenal. Using the eastbound direction as an example, the spreadsheet will look like this in "show formula" mode:



	A	B	C	D	E	F
1	**Example Headway Sheet #1**					
2						
3						
4			**Eastbound**			
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**
6						
7			0.25	=C7+(0.00069444*$Q$9)	=D7+(0.00069444*$Q$10)	=E7+(0.00069444*$Q$11)
8			=C7+$Q$35	=C8+(0.00069444*$Q$9)	=D8+(0.00069444*$Q$10)	=E8+(0.00069444*$Q$11)
9			=C8+$Q$35	=C9+(0.00069444*$Q$9)	=D9+(0.00069444*$Q$10)	=E9+(0.00069444*$Q$11)
10			=C9+$Q$35	=C10+(0.00069444*$Q$9)	=D10+(0.00069444*$Q$10)	=E10+(0.00069444*$Q$11)
11			=C10+$Q$35	=C11+(0.00069444*$Q$9)	=D11+(0.00069444*$Q$10)	=E11+(0.00069444*$Q$11)
12			=C11+$Q$35	=C12+(0.00069444*$Q$9)	=D12+(0.00069444*$Q$10)	=E12+(0.00069444*$Q$11)
13			=C12+$Q$35	=C13+(0.00069444*$Q$9)	=D13+(0.00069444*$Q$10)	=E13+(0.00069444*$Q$11)
14			=C13+$Q$35	=C14+(0.00069444*$Q$9)	=D14+(0.00069444*$Q$10)	=E14+(0.00069444*$Q$11)
15			=C14+$Q$35	=C15+(0.00069444*$Q$9)	=D15+(0.00069444*$Q$10)	=E15+(0.00069444*$Q$11)
16			=C15+$Q$35	=C16+(0.00069444*$Q$9)	=D16+(0.00069444*$Q$10)	=E16+(0.00069444*$Q$11)
17			=C16+$Q$35	=C17+(0.00069444*$Q$9)	=D17+(0.00069444*$Q$10)	=E17+(0.00069444*$Q$11)
18			=C17+$Q$35	=C18+(0.00069444*$Q$9)	=D18+(0.00069444*$Q$10)	=E18+(0.00069444*$Q$11)
19			=C18+$Q$35	=C19+(0.00069444*$Q$9)	=D19+(0.00069444*$Q$10)	=E19+(0.00069444*$Q$11)
20			=C19+$Q$35	=C20+(0.00069444*$Q$9)	=D20+(0.00069444*$Q$10)	=E20+(0.00069444*$Q$11)
21			=C20+$Q$35	=C21+(0.00069444*$Q$9)	=D21+(0.00069444*$Q$10)	=E21+(0.00069444*$Q$11)
22			=C21+$Q$35	=C22+(0.00069444*$Q$9)	=D22+(0.00069444*$Q$10)	=E22+(0.00069444*$Q$11)
23			=C22+$Q$35	=C23+(0.00069444*$Q$9)	=D23+(0.00069444*$Q$10)	=E23+(0.00069444*$Q$11)
24			=C23+$Q$35	=C24+(0.00069444*$Q$9)	=D24+(0.00069444*$Q$10)	=E24+(0.00069444*$Q$11)
25			=C24+$Q$35	=C25+(0.00069444*$Q$9)	=D25+(0.00069444*$Q$10)	=E25+(0.00069444*$Q$11)
26			=C25+$Q$35	=C26+(0.00069444*$Q$9)	=D26+(0.00069444*$Q$10)	=E26+(0.00069444*$Q$11)
27			=C26+$Q$35	=C27+(0.00069444*$Q$9)	=D27+(0.00069444*$Q$10)	=E27+(0.00069444*$Q$11)
28			=C27+$Q$35	=C28+(0.00069444*$Q$9)	=D28+(0.00069444*$Q$10)	=E28+(0.00069444*$Q$11)
29			=C28+$Q$35	=C29+(0.00069444*$Q$9)	=D29+(0.00069444*$Q$10)	=E29+(0.00069444*$Q$11)
30			=C29+$Q$35	=C30+(0.00069444*$Q$9)	=D30+(0.00069444*$Q$10)	=E30+(0.00069444*$Q$11)
31			=C30+$Q$35	=C31+(0.00069444*$Q$9)	=D31+(0.00069444*$Q$10)	=E31+(0.00069444*$Q$11)
32			=C31+$Q$35	=C32+(0.00069444*$Q$9)	=D32+(0.00069444*$Q$10)	=E32+(0.00069444*$Q$11)
33			=C32+$Q$35	=C33+(0.00069444*$Q$9)	=D33+(0.00069444*$Q$10)	=E33+(0.00069444*$Q$11)

This example shows the values of the filled-in spreadsheet:



	A	B	C	D	E	F	G	H	I	J	K
1	**Example Headway Sheet #1**										
2	ROUTE	97 Broad Street									
3	DAY	Weekday									
4			**Eastbound**					**Westbound**			
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**
6								6:15	6:26	6:40	6:48
7			6:00	6:08	6:22	6:33		6:45	6:56	7:10	7:18
8			6:30	6:38	6:52	7:03		7:15	7:26	7:40	7:48
9			7:00	7:08	7:22	7:33		7:45	7:56	8:10	8:18
10			7:30	7:38	7:52	8:03		8:15	8:26	8:40	8:48
11			8:00	8:08	8:22	8:33		8:45	8:56	9:10	9:18
12			8:30	8:38	8:52	9:03		9:15	9:26	9:40	9:48
13			9:00	9:08	9:22	9:33		9:45	9:56	10:10	10:18
14			9:30	9:38	9:52	10:03		10:15	10:26	10:40	10:48
15			10:00	10:08	10:22	10:33		10:45	10:56	11:10	11:18
16			10:30	10:38	10:52	11:03		11:15	11:26	11:40	11:48
17			11:00	11:08	11:22	11:33		11:45	11:56	12:10	12:18
18			11:30	11:38	11:52	12:03		12:15	12:26	12:40	12:48
19			12:00	12:08	12:22	12:33		12:45	12:56	13:10	13:18
20			12:30	12:38	12:52	13:03		13:15	13:26	13:40	13:48
21			13:00	13:08	13:22	13:33		13:45	13:56	14:10	14:18
22			13:30	13:38	13:52	14:03		14:15	14:26	14:40	14:48
23			14:00	14:08	14:22	14:33		14:45	14:56	15:10	15:18
24			14:30	14:38	14:52	15:03		15:15	15:26	15:40	15:48
25			15:00	15:08	15:22	15:33		15:45	15:56	16:10	16:18
26			15:30	15:38	15:52	16:03		16:15	16:26	16:40	16:48
27			16:00	16:08	16:22	16:33		16:45	16:56	17:10	17:18
28			16:30	16:38	16:52	17:03		17:15	17:26	17:40	17:48
29			17:00	17:08	17:22	17:33		17:45	17:56	18:10	18:18
30			17:30	17:38	17:52	18:03		18:15	18:26	18:40	18:48
31			18:00	18:08	18:22	18:33		18:45	18:56	19:10	19:18
32			18:30	18:38	18:52	19:03		19:15	19:26	19:40	19:48
33			19:00	19:08	19:22	19:33					

Since we have said the schedule operates until 7:00 PM, we will take the literal view that this means we provide a last trip at or near that time. That provides a 7:00 PM (19:00) final trip eastbound and either a 6:45 or 7:15 trip westbound. We choose arbitrarily to offer a 7:15 trip. We can partially justify it by being closer to the garage when the trip is over.

With the advent of computerized scheduling, use of the 24-hour clock, or military time, has become more common and is used in all our examples. Refer to the picture at right if you are not familiar with the 24-hour clock.

Our Simple Schedule in a Computerized Scheduling Package

Even if you have access to a computerized scheduling system, it is still important to go through this process. The scheduling system will certainly automate some of the things we've discussed—building multiple trips, calculating mileage and hours, and even potentially linking the trips. However, and we cannot stress this enough, the system will only produce quality outputs (i.e., schedules, blocks and runs) if the inputs have been properly developed. "Garbage in, garbage out" is the simplest way to put it.

So while it is true that you do not need to build an entire schedule from the start in Excel, it is still important to understand the elements of the scheduling process. Once you have defined the route, time points, running times, and distances in your system, trips are easy to create and manipulate. But what time should the trips start? How will the system link? How many buses will we need? These questions need to be asked and answered before any basic schedule is created.

We recommend that you build the schedule pattern just as if you were developing the schedule without a computerized scheduling system (i.e., in a spreadsheet). Just as this process allowed us to create a schedule that would link effectively in the spreadsheet, so too will it allow us to create a schedule that links effectively in your computerized scheduling system. Even sophisticated scheduling packages usually cannot resolve badly written schedules. For example, if we decided to schedule trips depart from "A" at :00 and :30, and from "D" at :25 and :55, such a schedule pattern would result in an additional vehicle whether or not a scheduling package is used. The automated scheduler does offer some inherent capabilities to view obvious issues and work interactively with the schedules.

At this point you can begin blocking. As mentioned before we started, we already "know the answer" to how many buses are required before we even do any blocking. We have in fact defined the schedule to ensure our answer. The next chapter discusses blocking in greater detail.

LEVEL 1

End of Basic Schedule Building.
The Intermediate Section of Schedule Building continues on the next page.

To jump to Schedule Blocking, go to page 4-1.

Tip When evaluating alternate scheduling frequencies on a route, always recalculate the round trip cycle time and check the efficiency of the headway against the cycle. You may find that you can increase service by making the cycle more efficient.

Tip Running "hot" or ahead of schedule is a much more serious problem for riders than running behind schedule. The timetable is essentially a "contract" between the passenger and the transit system that promises that if the passenger arrives at the stop on time the bus will be there to pick them up. Leaving a stop early means that passengers who arrive at the stop on time may have to wait more than an entire headway for the bus to come.

3.2 A Slightly More Intricate Schedule

LEVEL 2A

Let's continue from where we left off. Again we assume you are building the schedule in the spreadsheet, but many of the approaches carry over into computerized scheduling. Suppose you have done a fabulous job of constructing this schedule, just as a good scheduler should, and you have beaten the cost estimate contained in the operating budget. There is enough funding left over to provide additional peak hour service. Peak hours have been defined for us as 6:00 – 9:00 AM and 3:00 – 6:00 PM (15:00 – 18:00).

We have some options. (We generally do…that is what makes scheduling seem so daunting for new schedulers.) We could provide a 15-minute service, which would double the service of the existing schedule, or we could go from our present 30- to a 20-minute headway, an approximate 50% increase in service. Of course, we could provide even better peak service than 15 minutes. Since our remaining service budget is not unlimited, we want to look at both options. This is a very typical task asked of schedulers—"how much will it cost for this frequency, that frequency, or span of service?"

Back again to our old friend the Round trip Cycle. To refresh our memory, the minimum acceptable cycle (round-trip running time of 66 minutes plus the prescribed minimum layover) is 73 minutes. To provide a 20-minute service, look at how multiples of 20 work with that cycle: 20, 40, 60, 80, etc. A cycle of 80 would yield layover of 14 minutes, which is 21%. Therefore, an increase to 20–minute service would require one more bus (for a total of four—80 minutes divided by the 20-minute headway) in the cycle.

For a 15-minute headway we need to look at multiples of 15: 15, 30, 45, 60, 75, 90, etc. A 75-minute cycle would allow for layover of nine minutes, which is acceptable under our contractual requirements (or operating practices, if there is no provision in the contract). But the real question is whether, knowing the practical conditions of traffic congestion and operating time variability, nine minutes of layover every 75 minutes is enough to reasonably guarantee that buses will recover from delays and leave on time for their next trip. A 75-minute round trip cycle would require 5 buses, one more than the 20 minute headway solution, and 2 more than the initial 30-minute service proposed. Of course we could also use the 90-minute base period cycle, which would preserve the 12 minutes or so at each end of the route, but that would be considered excessive if a better alternative were available.

Let's now apply a quick rule-of-thumb about costs: the periods of the day when additional buses would operate total about seven hours (two three-hour periods during the morning and afternoon peak periods plus the in and out deadhead time). So, a 20-minute peak headway would add seven hours, while a 15-minute peak would add 14 (seven hours x 2 buses). Apply your system's cost per hour to that and you get a reasonably accurate cost estimate even before you start building (or in our case, revising) your schedule—again the point of knowing the outcomes before any real schedule writing is undertaken.

Which do you choose? The ideal choice is the option that provides the greatest amount of service for which funding is available. But transit systems face the economic problem of unlimited wants and limited resources. Therefore we do not want to commit more resources than justified either by the known or the projected ridership—service standards, or your service planners, will be able to assist in making this decision. Then too, there is the concern that peak hour buses add to the inefficiency of the schedule in that they require equipment that only gets used for part of the day. They could potentially make for a less efficient runcut, increasing the number of **split runs** that will have to be built or ultimately winding up as **pieces** that cannot be worked into a full run. As you can see, the scheduler is torn between these two positions.

In this particular case, the decision has been made to go with the 15-minute service, as the system can afford it and it offers a better connection strategy with other routes that operate on a 30-minute headway (at a 20-minute headway, this route would miss one of two hourly connections with other 30-minute routes—this is not a minor consideration). Remembering our round trip cycle calculation, five buses would give us a 75-minute cycle (we need a minimum of 73) while six buses would take us to the same 90-minute cycle that we currently use during the day for our 30-minute service. There is no question here. Five buses work within our minimums. We do not need all of the layover we currently apply in the base period. We would cut that down if we could.

To create the schedule, we simply insert a few rows during the peaks and add in the extra trips between the schedules—right?

But wait. It is not quite as easy as that. You can fill in-between trips eastbound beginning with the blank row after 6:00 under time point "A." Continue until you reach the 9:00 trip. This will add new trips beginning at 6:15 and continuing at :15 and :45 up to 8:45. That will meet the criteria we set for the **AM peak period**. Beginning with the 9:00 trip, we resume our 30-minute service and can leave these trips just as we wrote them on the first iteration of the schedule.

We can do this also for the **PM peak period**. We add trips between the 15:00 and 18:00 trips, giving us a solid 15-minute service for this three hour period, as shown on the following page:

split run

A run containing two or more pieces of work separated by a break over one hour in length. Also known as a "swing run." At some systems, three-piece split runs are allowed, but one of the breaks (or "swings") is usually paid whereas in two-piece split runs the break is generally not paid. Split runs tend to be used to allow both peaks to be covered by one operator since the work day would otherwise be too long for a straight run.

pieces

Portions of a run, especially distinct portions separated by a break.

two-piece run

A run made up of two pieces of work separated by an interval of time. The pieces will usually be on different blocks and may be on different routes.

three-piece run

A run made up of three pieces of work separated by two intervals of time. Generally, one of the intervals in a three-piece run is paid time.

Tip Even if your system does not have a required amount of layover, always ask yourself whether the route can be expected to run on time given traffic conditions and a designated amount of layover.

AM peak period

The period in the morning when the greatest level of service is provided, typically 6 to 9 AM.

PM Peak period

The period in the afternoon when the greatest level of service is provided, typically 3 to 7 PM.

1	**Example Headway Sheet #2**												
2	ROUTE	97 Broad Street											
3	DAY	Weekday											
4			**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**	**Next Trip**	***Pull In***
								6:00					
6	3	*5:55*						6:15	6:26	6:40	6:48	7:00	
								6:30					
7	1	*5:50*	6:00	6:08	6:22	6:33		6:45	6:56	7:10	7:18	7:30	
			6:15					7:00					
8	2	*6:20*	6:30	6:38	6:52	7:03		7:15	7:26	7:40	7:48	8:00	
			6:45					7:30					
9	3		7:00	7:08	7:22	7:33		7:45	7:56	8:10	8:18	8:30	
			7:15					8:00					
10	1		7:30	7:38	7:52	8:03		8:15	8:26	8:40	8:48	9:00	
			7:45					8:30					
11	2		8:00	8:08	8:22	8:33		8:45	8:56	9:10	9:18	9:30	
			8:15					9:00					
12	3		8:30	8:38	8:52	9:03		9:15	9:26	9:40	9:48	10:00	
			8:45										
13	1		9:00	9:08	9:22	9:33		9:45	9:56	10:10	10:18	10:30	
14	2		9:30	9:38	9:52	10:03		10:15	10:26	10:40	10:48	11:00	
15	3		10:00	10:08	10:22	10:33		10:45	10:56	11:10	11:18	11:30	
16	1		10:30	10:38	10:52	11:03		11:15	11:26	11:40	11:48	12:00	
17	2		11:00	11:08	11:22	11:33		11:45	11:56	12:10	12:18	12:30	
18	3		11:30	11:38	11:52	12:03		12:15	12:26	12:40	12:48	13:00	
19	1		12:00	12:08	12:22	12:33		12:45	12:56	13:10	13:18	13:30	
20	2		12:30	12:38	12:52	13:03		13:15	13:26	13:40	13:48	14:00	
21	3		13:00	13:08	13:22	13:33		13:45	13:56	14:10	14:18	14:30	
22	1		13:30	13:38	13:52	14:03		14:15	14:26	14:40	14:48	15:00	
23	2		14:00	14:08	14:22	14:33		14:45	14:56	15:10	15:18	15:30	
24	3		14:30	14:38	14:52	15:03		15:15	15:26	15:40	15:48	16:00	
25								15:30					
	1		15:00	15:08	15:22	15:33		15:45	15:56	16:10	16:18	16:30	
26			15:15					16:00					
	2		15:30	15:38	15:52	16:03		16:15	16:26	16:40	16:48	17:00	
27			15:45					16:30					
	3		16:00	16:08	16:22	16:33		16:45	16:56	17:10	17:18	17:30	
28			16:15					17:00					
	1		16:30	16:38	16:52	17:03		17:15	17:26	17:40	17:48	18:00	
29			16:45					17:30					
	2		17:00	17:08	17:22	17:33		17:45	17:56	18:10	18:18	18:30	
30			17:15					18:00					
	3		17:30	17:38	17:52	18:03		18:15	18:26	18:40	18:48	19:00	
31			17:45										
32	1		18:00	18:08	18:22	18:33		18:45	18:56	19:10	19:18		*19:28*
33	2		18:30	18:38	18:52	19:03		19:15	19:26	19:40	19:48		*19:58*
34	3		19:00	19:08	19:22	19:33							*19:53*

Slipping and Sliding

We mentioned the possibility of wanting to "slip or slide" trips before we filled in intermediate times. Basically the term relates to moving the trips in one or both directions. We might want to do this for the following reasons:

- To give more or less layover at one end of the route due to operational reasons, such as the lack of a decent place to park a bus
- To adjust an intermediate time for a particular reason, such as a positive meet with another route
- To meet school bell times (in which case we might want to move only one or two trips)

Revising this eastbound direction was simple. But this was done without regard to blocking impacts (remember we said—know the answer before you get into the detailed schedule writing). Our previous schedule pattern had 12 minutes of layover at either end, and now we have decided that a total of 9 minutes per round-trip is going to be applied.

We have 66 minutes of running time within a 75-minute window (5 x 15-minute headway). We can divide the layover equally between both terminals or give more or most to one terminal. It is not wise to give none at all, because that provides no relief valve for late arriving buses. Since this is a theoretical schedule and we really do not know the traffic conditions at Terminal A versus D, we can pretty much decide our own strategy. So the westbound trips are going to have to move to accommodate the smaller layover we have planned. This is part of the process we call **slipping and sliding**.

Effectively we are revisiting the schedule pattern to decide how the peak will work. This raises an important consideration in developing schedules—that the peak schedule pattern may be different from the off-peak schedule pattern. Why? There may be several reasons, including:

- Different frequencies, a regular occurrence since the bulk of travel is during peak times.
- Different running times during the day. Running times may change several times during the day to take into account different operating speeds due to congestion, loads, or other factors. In this example, we continue to assume constant running times all day.
- The need to have specific departure times at specific times of day, i.e., to connect with other service or modes whose schedules change at a certain time.
- To adjust the blocking, perhaps to schedule with less layover during the peaks (to minimize **peak vehicles)**, but to allow more time in the off peak where resources aren't at such a premium.

slipping and sliding

The process of shifting one or more trips forward or backward in time to achieve a specific purpose. Also known as "trip shifting."

peak vehicles

The maximum number of vehicles required to operate the route at the required headway. Quickly calculated as: cycle time divided by headway. Also referred to as "peak vehicle requirement."

base vehicles

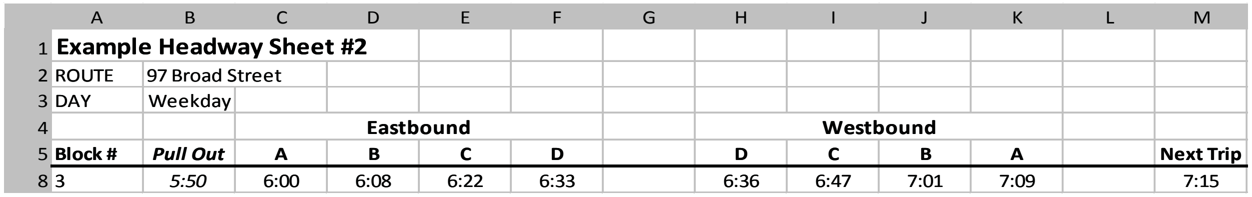
The number of vehicles required to operate the route at the required headway during the base period. Quickly calculated as: cycle time in the base period divided by headway in the base period. Also referred to as "base period vehicle requirement."

Tip Some agencies combine operator rest time ("layover") with time to get back on schedule ("recovery") and others have separate standards and contract rules for each. Know the rules of your agency before you begin to schedule!

In this case we have decided that our preference would be to give three minutes at "D" as the "away" terminal and the remaining six at "A." Three provides the buffer we are looking for. Remember that we have done a bang-up job of calculating the running time for accuracy, so we are only concerned with providing that extra buffer for conditions beyond the ordinary. The six minutes at "A" provide a more reasonable time for the operator to get off the bus and stretch his/her legs.

We have also decided that we want to keep our existing :00 and :30 eastbound departure times (assuming in this case we have a connection we want to make at "A").

Following this strategy means we will have to slide our existing westbound trips earlier by nine minutes, so that the 6:00 trip arriving at 6:33 will now leave at 6:36 instead of the present 6:45. All of this can be looked at as we develop our schedule patterns sheet, which for the AM peak now looks like the following:



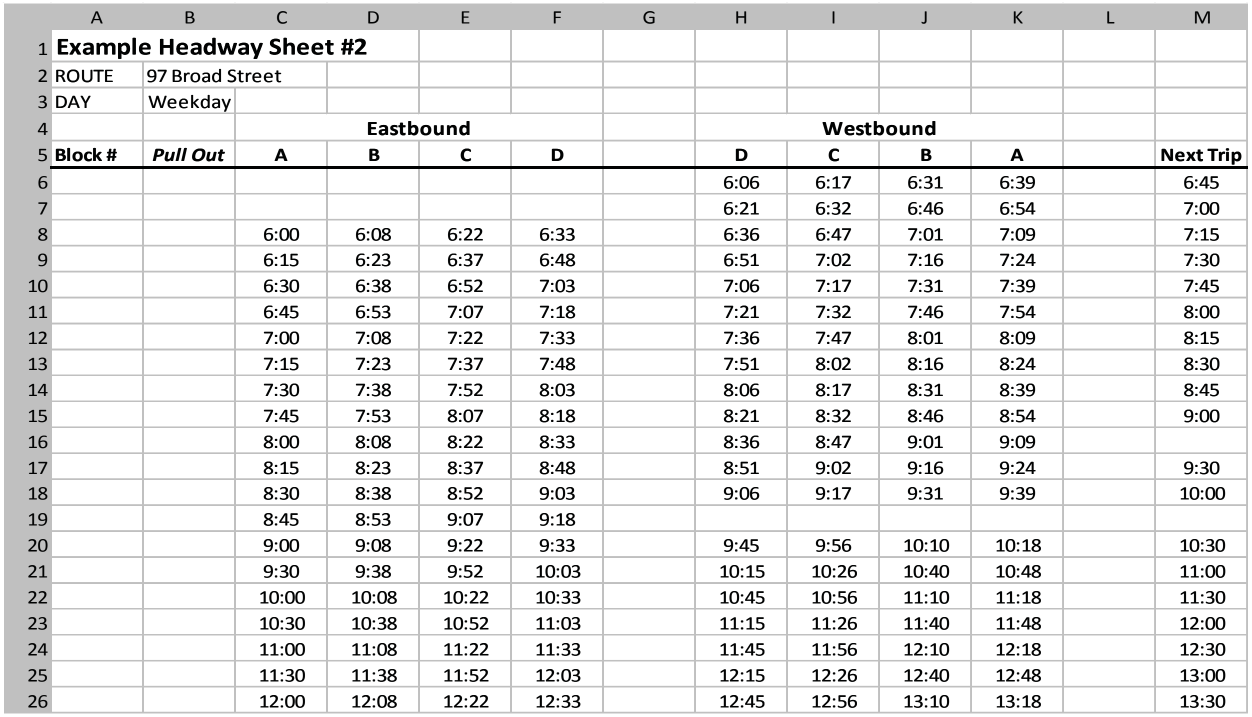
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Example Headway Sheet #2**												
2	ROUTE	97 Broad Street											
3	DAY	Weekday											
4			**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**
8	3	*5:50*	6:00	6:08	6:22	6:33		6:36	6:47	7:01	7:09		7:15

During the peaks this becomes a 15-minute repeating schedule pattern. So again our first bus gets back to make the 7:15 departure, giving a 75-minute cycle. Or to prove the theory, we will need buses for the 6:00, 6:15, 6:30, 6:45 and 7:00 eastbound departures (5 in all).

Some of the above could have been carried out a little differently in some computerized scheduling systems. For example the ability to drag trips along a time distance graph can visually represent the process of creating or altering schedule patterns. It's pretty simple—move the trip until you see it "fit" into the linkup. Typically this should be done with one round-trip, effectively recreating the schedule pattern procedure anyway, before rebuilding the schedule.

Refining the Schedule

Now we fill out the rest of the trips to meet the intended schedule pattern—departures from "A" at :00, :15, :30 & :45; departures from "D" at :06, :21, :36 & :51 in the peaks, but keeping midday the same:



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Example Headway Sheet #2**												
2	ROUTE	97 Broad Street											
3	DAY	Weekday											
4			**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**
6								6:06	6:17	6:31	6:39		6:45
7								6:21	6:32	6:46	6:54		7:00
8			6:00	6:08	6:22	6:33		6:36	6:47	7:01	7:09		7:15
9			6:15	6:23	6:37	6:48		6:51	7:02	7:16	7:24		7:30
10			6:30	6:38	6:52	7:03		7:06	7:17	7:31	7:39		7:45
11			6:45	6:53	7:07	7:18		7:21	7:32	7:46	7:54		8:00
12			7:00	7:08	7:22	7:33		7:36	7:47	8:01	8:09		8:15
13			7:15	7:23	7:37	7:48		7:51	8:02	8:16	8:24		8:30
14			7:30	7:38	7:52	8:03		8:06	8:17	8:31	8:39		8:45
15			7:45	7:53	8:07	8:18		8:21	8:32	8:46	8:54		9:00
16			8:00	8:08	8:22	8:33		8:36	8:47	9:01	9:09		
17			8:15	8:23	8:37	8:48		8:51	9:02	9:16	9:24		9:30
18			8:30	8:38	8:52	9:03		9:06	9:17	9:31	9:39		10:00
19			8:45	8:53	9:07	9:18							
20			9:00	9:08	9:22	9:33		9:45	9:56	10:10	10:18		10:30
21			9:30	9:38	9:52	10:03		10:15	10:26	10:40	10:48		11:00
22			10:00	10:08	10:22	10:33		10:45	10:56	11:10	11:18		11:30
23			10:30	10:38	10:52	11:03		11:15	11:26	11:40	11:48		12:00
24			11:00	11:08	11:22	11:33		11:45	11:56	12:10	12:18		12:30
25			11:30	11:38	11:52	12:03		12:15	12:26	12:40	12:48		13:00
26			12:00	12:08	12:22	12:33		12:45	12:56	13:10	13:18		13:30

Transitioning

Besides round trip cycles (and accuracy, of course), the most interesting concept to introduce to a new scheduler is transitioning. Transitioning involves the smoothing of the change in headway, running time, or both. On our first schedule we had the same running time and headway all day, so transitioning was not a factor. This second schedule adds the complication of changing from a 15-minute during the AM peak to a 30-minute in the midday, back to a 15-minute in the PM Peak and finally back to a 30-minute headway during the course of an operating day. The next section will introduce a schedule with variable running time. Learning to smooth these changes is an integral part of being able to develop quality schedules.

Tip Transitioning allows service to ease into a new schedule pattern as demand changes gradually over the service day.

For our current schedule, we want to review how well we have handled these headway transitions. First, look at the end of the AM peak. Notice that eastbound, we abruptly stop providing a 15-minute service and go directly into a 30. On a smaller or lighter route, one where policy headways are driving the service strategy, this is perfectly acceptable. If we were driven by demand, there might be a period where the headways would widen (service would reduce) maybe to a 20, then a 30-minute headway. However, the service policy is the deciding factor in this case, so we go to the base 30 as soon as our service plan tells us to do so.

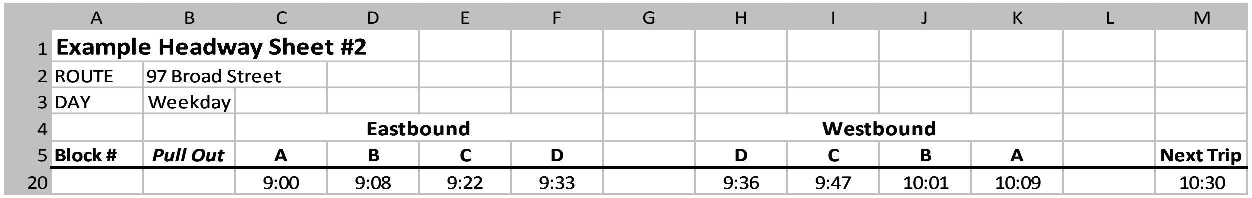
The westbound side is not so cut and dried, because the leaving times changed to accommodate the five-bus round trip cycle layover scheme. As the schedule shows, we shift back to the :15/:45 leave times as we transition out of the peak. Notice that we go from 8:51 to 9:15, which is a 24-minute headway. That headway is a combination of the 15- and a nine-minute adjustment in order to get the westbound trips onto our three-bus base cycle. It would have been easy to make the next trip 9:06, continuing the 15-minute headway. But the next trip at 9:45 would have been 39 minutes later, which is not acceptable when a 30-minute headway is called for.

A similar shift is made going into the PM peak westbound. We move what normally would have been the 15:15 trip up (forward) by nine minutes to become the 15:06 and the start of our :06, :21, :36 and :51 leaving strategy which puts layover times where we decided earlier we wanted them. You can make these transitions work for you or against you; it is a matter of learning how to do the former. There is no one rule that works every time, because every transition is different. But a good scheduler always studies a headway (or running time) transition to see the result.

If the result yields a wider headway than you are planning to operate after the change, then you need to look at shifting an earlier trip. In this example, we didn’t want to go from a 15 to a 36. We could go from a 15, to a 21, to a 30, which is progressively widening the headway. The same situation in reverse is true for shortening the headway going into the PM peak.

This is a simple example of transitioning, but its principles hold true even in the most complex schedule.

A slightly different approach to the transition from peak to off-peak (and again back to peak) would be to provide a consistent set of departure times westbound throughout the day. This leaves us with a decision—at a 30-minute headway do we choose :00/:30 or :15/:45 eastbound, and :06/:36 or :21/:51 westbound? Which to choose may depend on any other connections, at what time you transition to the off peak, or just a general preference. Either would work. In our case we choose :00/:30 eastbound and :06/:36 westbound. This maintains the 24 minutes of layover per round-trip, and the three off-peak buses. In effect we have revisited the off-peak schedule entirely to keep consistent departure times with the peaks. The off-peak schedule pattern now looks like this:



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Example Headway Sheet #2**												
2	ROUTE	97 Broad Street											
3	DAY	Weekday											
4			**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**
20			9:00	9:08	9:22	9:33		9:36	9:47	10:01	10:09		10:30

Note that one disadvantage of this approach is that the layover time at point A is now 21 minutes. Many schedulers would be uncomfortable with this amount of layover, and might choose the first approach to avoid a long layover at one point. Others might tolerate it for the sake of consistent departure times.

Now we simply build the schedule according to the schedule pattern. If your formulas are correct (and of course they are!), all intermediate end times will simply adjust. And departure times can be calculated simply by changing the multiplier (or the minutes, if you are using the time function) to 15 (i.e., the trip start time is the previous time plus 15 minutes) during the peaks.

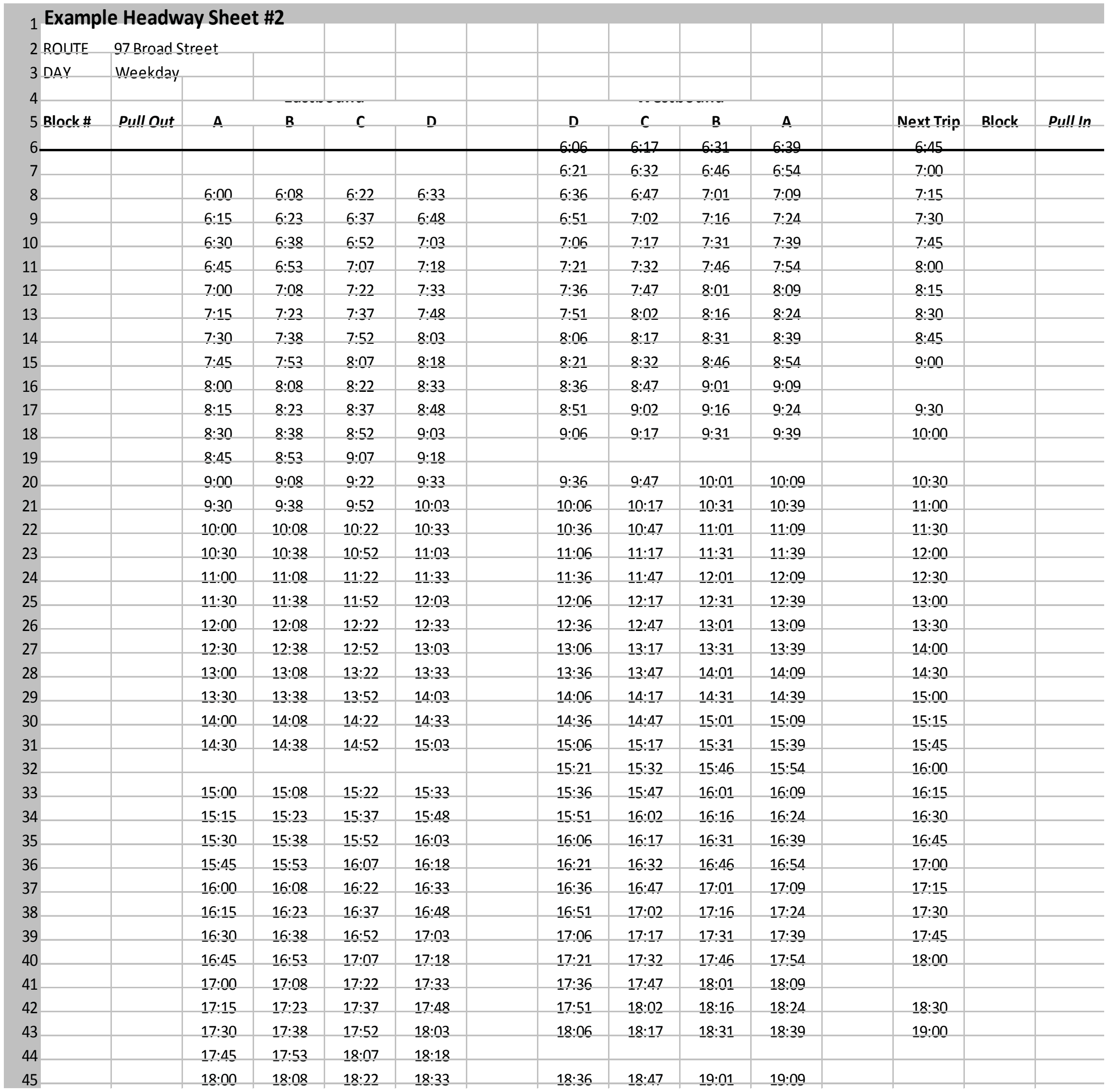
For the PM peak begin the 15-minute schedule at 15:00 eastbound and 15:06 westbound and continue until the 18:00/18:06 trip. Look at your next trips. They should be six minutes after the arrival time at Point A. Go ahead and add in your Next Trip times for the whole sheet.

The final schedule for 15-minute peak service on Route 97 under this approach is shown on the next page.

As for our simple schedule, the use of a computerized scheduling package will make the re-generation of the schedule much simpler and less prone to error. In this case you could simply delete the westbound trips all at once, keep the existing eastbound, add the new eastbound peak trips, and regenerate the entire westbound schedule, all with relative ease.

Use of time/distance and other graphics contained in computerized systems allows a good visual representation of transitioning. Computerized systems also allow the impacts of altered transitioning approaches to be seen immediately (e.g., breaking planned hooks or increasing the number of buses).

Tip Transitioning allows service to ease into a new pattern, generally matching service to demand which often changes more gradually over the service day.



1	**Example Headway Sheet #2**														
2	ROUTE	97 Broad Street													
3	DAY	Weekday													
4															
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	**Block**	***Pull In***
6								6:06	6:17	6:31	6:39		6:45		
7								6:21	6:32	6:46	6:54		7:00		
8			6:00	6:08	6:22	6:33		6:36	6:47	7:01	7:09		7:15		
9			6:15	6:23	6:37	6:48		6:51	7:02	7:16	7:24		7:30		
10			6:30	6:38	6:52	7:03		7:06	7:17	7:31	7:39		7:45		
11			6:45	6:53	7:07	7:18		7:21	7:32	7:46	7:54		8:00		
12			7:00	7:08	7:22	7:33		7:36	7:47	8:01	8:09		8:15		
13			7:15	7:23	7:37	7:48		7:51	8:02	8:16	8:24		8:30		
14			7:30	7:38	7:52	8:03		8:06	8:17	8:31	8:39		8:45		
15			7:45	7:53	8:07	8:18		8:21	8:32	8:46	8:54		9:00		
16			8:00	8:08	8:22	8:33		8:36	8:47	9:01	9:09				
17			8:15	8:23	8:37	8:48		8:51	9:02	9:16	9:24		9:30		
18			8:30	8:38	8:52	9:03		9:06	9:17	9:31	9:39		10:00		
19			8:45	8:53	9:07	9:18									
20			9:00	9:08	9:22	9:33		9:36	9:47	10:01	10:09		10:30		
21			9:30	9:38	9:52	10:03		10:06	10:17	10:31	10:39		11:00		
22			10:00	10:08	10:22	10:33		10:36	10:47	11:01	11:09		11:30		
23			10:30	10:38	10:52	11:03		11:06	11:17	11:31	11:39		12:00		
24			11:00	11:08	11:22	11:33		11:36	11:47	12:01	12:09		12:30		
25			11:30	11:38	11:52	12:03		12:06	12:17	12:31	12:39		13:00		
26			12:00	12:08	12:22	12:33		12:36	12:47	13:01	13:09		13:30		
27			12:30	12:38	12:52	13:03		13:06	13:17	13:31	13:39		14:00		
28			13:00	13:08	13:22	13:33		13:36	13:47	14:01	14:09		14:30		
29			13:30	13:38	13:52	14:03		14:06	14:17	14:31	14:39		15:00		
30			14:00	14:08	14:22	14:33		14:36	14:47	15:01	15:09		15:15		
31			14:30	14:38	14:52	15:03		15:06	15:17	15:31	15:39		15:45		
32								15:21	15:32	15:46	15:54		16:00		
33			15:00	15:08	15:22	15:33		15:36	15:47	16:01	16:09		16:15		
34			15:15	15:23	15:37	15:48		15:51	16:02	16:16	16:24		16:30		
35			15:30	15:38	15:52	16:03		16:06	16:17	16:31	16:39		16:45		
36			15:45	15:53	16:07	16:18		16:21	16:32	16:46	16:54		17:00		
37			16:00	16:08	16:22	16:33		16:36	16:47	17:01	17:09		17:15		
38			16:15	16:23	16:37	16:48		16:51	17:02	17:16	17:24		17:30		
39			16:30	16:38	16:52	17:03		17:06	17:17	17:31	17:39		17:45		
40			16:45	16:53	17:07	17:18		17:21	17:32	17:46	17:54		18:00		
41			17:00	17:08	17:22	17:33		17:36	17:47	18:01	18:09				
42			17:15	17:23	17:37	17:48		17:51	18:02	18:16	18:24		18:30		
43			17:30	17:38	17:52	18:03		18:06	18:17	18:31	18:39		19:00		
44			17:45	17:53	18:07	18:18									
45			18:00	18:08	18:22	18:33		18:36	18:47	19:01	19:09				

Finishing Up

Now review your schedule. Does this give us 15-minute service for the whole of the peak period as defined earlier? Is the transition from peak to off-peak and back again the way we want it? If so, we have achieved the results we planned for in our schedule pattern-building exercise.

As with the first schedule, take time to look over all aspects of the schedule for completeness and to catch any obvious errors—those things that have changed (or maybe you have failed to change) as the result of the adjustments introduced from the original schedule. That should do it. We now have another schedule ready for the blocking process.

LEVEL
2A

End of Intermediate Schedule Building, Part A

Intermediate Schedule Building, Part B continues on the next page.

To jump to Schedule Blocking, go to page 4-1.

3.3 Working on a More Intricate Schedule

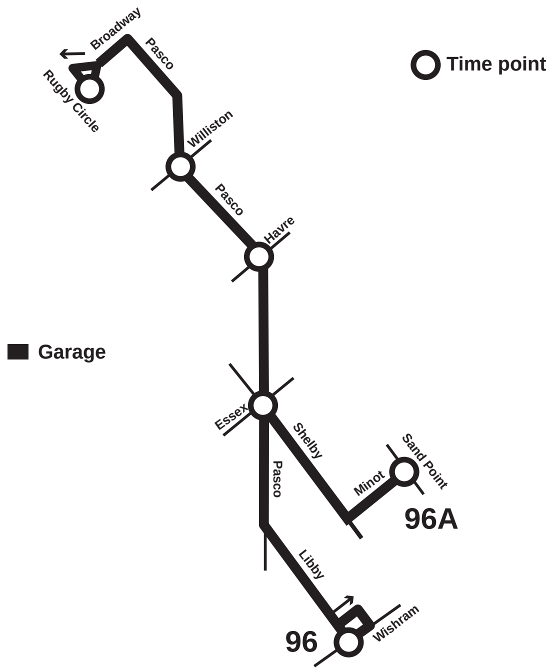
LEVEL 2B

Up to this point, new or trial schedules have relied on policy headways and calculated running times for schedule development and construction. Headways and running times are the basic building blocks of all schedules. While they are sometimes given to the scheduler, as in the previous exercises, it is often the responsibility of the scheduler to build and adjust schedules based on an analysis of passenger load data and actual running time information collected by **traffic checkers**.

As you continue to work your way through this manual, the examples become more complex and introduce new elements of scheduling. In this section, you will learn how to identify potential schedule changes based on variations in passenger load and running times. You will also learn to address the need for different running times throughout the day, and how to “smooth” the transition between periods of the day with different running times. Then in the advanced section, put these changes into practice by developing a revised schedule.

The schedule in this exercise, for Route 96—Pasco Avenue, is typical of many found on medium to large transit systems. It has headways which vary, both by time of day and direction. It contains running times that also change throughout the operating day. It features multiple service patterns and a larger **peak-to-base ratio**, meaning that it has a significant peak service that is about 40% greater than the amount of service operated during the base period between the peaks. Service then tapers off during the evening period and into late night. A map and the headway sheet for weekday service on Route 96 are shown below.

Route 96—Pasco Avenue



Tip Even if you are new to scheduling, do not be intimidated by the schedule and all of its detail. Even the most complex schedule can be understood if you review it one portion at a time.

traffic checkers

Individuals who conduct ride checks or point checks to collect ridership and time-related data.

peak-to-base ratio

The ratio between the number of buses or trains required to operate the schedule during the higher of the peak periods and by the number of buses in service in the “base” period between the peaks.   A peak to base ratio of 2.0 means that twice as many buses are required to operate peak period service as midday service. The peak-to-base ratio greatly influences the runcut in terms of the number of straight and split runs that are possible. A higher ratio means more split runs.

SCHEDULE SHEET

Route 96　　IN EFF: September 15, 2007
MONDAY THRU FRIDAY

Part 1

NORTHBOUND　　SOUTHBOUND

BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	IN GAR	LVE.
5	4:10								4:20	4:28	4:35	4:43		4:53		5:05
1	3:45	4:05		4:18	4:26	4:33	4:41		4:50	4:58	5:05	5:13		5:23		5:35
6	4:55								5:05	5:13	5:20	5:28	5:37			5:49
3	4:05	4:35		4:48	4:56	5:03	5:11		5:20	5:29	5:37	5:47		5:57		6:05
7	4:39		4:59	5:08	5:16	5:23	5:31		5:35	5:44	5:52	6:02	6:12			6:19
5		5:05		5:19	5:29	5:37	5:46		5:50	5:59	6:07	6:17		6:27		6:45
9	4:59		5:19	5:29	5:39	5:47	5:56		6:05	6:14	6:22	6:32	6:42			6:57
1		5:35		5:49	5:59	6:07	6:16		6:20	6:29	6:37	6:47		6:57		7:05
6			5:49	5:59	6:09	6:17	6:26		6:35	6:44	6:52	7:02	7:12			7:17
3		6:05		6:19	6:29	6:37	6:46		6:50	7:01	7:10	7:21		7:32		7:45
7			6:19	6:29	6:39	6:47	6:56		7:05	7:16	7:25	7:36	7:46			7:57
8	5:55	6:25		6:39	6:50	6:59	7:10		7:15	7:26	7:35	7:46		7:57		8:05
4	6:17		6:37	6:49	7:00	7:09	7:20		7:25	7:36	7:45	7:56	8:06			8:23
5		6:45		6:59	7:10	7:19	7:30		7:35	7:46	7:55	8:06		8:17		8:35
9			6:57	7:09	7:20	7:29	7:40		7:45	7:56	8:05	8:16	8:26		8:46	
1		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37		9:05
6			7:17	7:29	7:40	7:49	8:00		8:05	8:16	8:25	8:36	8:46			8:53
10	6:55	7:25		7:39	7:50	7:59	8:10		8:15	8:26	8:35	8:46		8:57	9:17	
2	7:17		7:37	7:49	8:00	8:09	8:20		8:25	8:36	8:45	8:56	9:06			9:23
3		7:45		7:59	8:10	8:19	8:30		8:35	8:46	8:55	9:06		9:17		9:35
7			7:57	8:09	8:20	8:29	8:40		8:45	8:56	9:05	9:16	9:26		9:46	
8		8:05		8:19	8:30	8:39	8:50		8:55	9:06	9:15	9:26		9:37	9:57	
4			8:23	8:34	8:44	8:52	9:02		9:07	9:18	9:27	9:38	9:48			9:53
5		8:35		8:48	8:58	9:06	9:16		9:22	9:31	9:38	9:48		9:59		10:05
6			8:53	9:04	9:14	9:21	9:31		9:37	9:46	9:53	10:03	10:13			10:23
1		9:05		9:18	9:28	9:35	9:44		9:52	10:01	10:08	10:18		10:29		10:35
2			9:23	9:33	9:43	9:50	9:59		10:07	10:16	10:23	10:33	10:43			10:53
3		9:35		9:48	9:58	10:05	10:14		10:22	10:31	10:38	10:48		10:59		11:05
4			9:53	10:03	10:13	10:20	10:29		10:37	10:46	10:53	11:03	11:13			11:23
5		10:05		10:18	10:28	10:35	10:44		10:52	11:01	11:08	11:18		11:29		11:35
6			10:23	10:33	10:43	10:50	10:59		11:07	11:16	11:23	11:33	11:43			11:53
1		10:35		10:48	10:58	11:05	11:14		11:22	11:31	11:38	11:48		11:59		12:05
2			10:53	11:03	11:13	11:20	11:29		11:37	11:46	11:53	12:03	12:13			12:23
3		11:05		11:18	11:28	11:35	11:44		11:52	12:01	12:08	12:18		12:29		12:35
4			11:23	11:33	11:43	11:50	11:59		12:07	12:16	12:23	12:33	12:43			12:53
5		11:35		11:48	11:58	12:05	12:14		12:22	12:31	12:38	12:48		12:59		13:05
6			11:53	12:03	12:13	12:20	12:29		12:37	12:46	12:53	13:03	13:13			13:23
1		12:05		12:18	12:28	12:35	12:44		12:52	13:01	13:08	13:18		13:29		13:35
2			12:23	12:33	12:43	12:50	12:59		13:07	13:16	13:23	13:33	13:43			13:53
3		12:35		12:48	12:58	13:05	13:14		13:22	13:31	13:38	13:48		13:59		14:05
4			12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:13			14:23
5		13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:29		14:35
6			13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:43			14:53

SCHEDULE SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

Part 2

				NORTHBOUND								SOUTHBOUND				
BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	IN GAR	LVE.
1		13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		14:59		15:05
2			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:13			15:23
3		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:29		15:35
4			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:43			15:48
5		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		15:59		16:05
12	15:23								15:33	15:43	15:50	16:01	16:11			16:15
6			14:53	15:03	15:14	15:21	15:31		15:45	15:55	16:02	16:13		16:24		16:32
1		15:05		15:18	15:29	15:36	15:46		15:57	16:07	16:14	16:25	16:35			16:45
2			15:23	15:33	15:44	15:51	16:01		16:09	16:19	16:26	16:37		16:48		16:52
3		15:35		15:48	15:59	16:06	16:16		16:20	16:31	16:39	16:50	17:01			17:05
4			15:48	15:58	16:09	16:16	16:26		16:30	16:41	16:49	17:00		17:12		17:15
11	15:53			16:08	16:19	16:26	16:36		16:40	16:51	16:59	17:10	17:21			17:28
5		16:05		16:18	16:29	16:36	16:46		16:50	17:01	17:09	17:20		17:32		17:36
12			16:15	16:25	16:36	16:44	16:55		17:00	17:11	17:19	17:30	17:41			17:53
13	16:20			16:35	16:46	16:54	17:05		17:10	17:21	17:29	17:40		17:52		18:05
6		16:32		16:45	16:56	17:04	17:15		17:20	17:31	17:39	17:50	18:01		18:21	
1			16:45	16:55	17:06	17:14	17:25		17:30	17:40	17:48	17:58		18:10		18:35
2		16:52		17:05	17:16	17:24	17:35		17:40	17:50	17:58	18:08	18:19			18:23
3			17:05	17:15	17:26	17:34	17:45		17:52	18:02	18:10	18:20		18:32	18:52	
4		17:15		17:28	17:39	17:47	17:58		18:05	18:15	18:23	18:33	18:44			18:53
11			17:28	17:38	17:49	17:57	18:08								18:18	
5		17:36		17:49	17:59	18:06	18:15		18:20	18:30	18:38	18:48		19:00		19:05
12			17:53	18:03	18:13	18:20	18:29		18:35	18:45	18:53	19:03	19:14			19:23
13		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:15		19:26		19:35
2			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:30	19:40			19:53
1		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:50		20:01		20:06
4			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:10	20:20			20:28
5		19:05		19:18	19:28	19:35	19:44								19:54	
12			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:30		20:41		20:46
13		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:50	21:00			21:08
2			19:53	20:03	20:12	20:19	20:26								20:36	
1		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:10		21:21		21:26
4			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35			21:48
12		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56		22:06
13			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15			22:28
1		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36		22:46
4			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55			23:08
12		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16		23:26
13			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35			23:48
1		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56		0:06
4			23:08	23:18	23:26	23:32	23:39								23:49	
12		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36	0:56	
13			23:48	23:58	0:06	0:12	0:19								0:29	
1		0:06		0:18	0:26	0:32	0:39								0:49	

Tip The most productive transit routes are those that have balanced demand in both directions. Routes with a very pronounced peak direction may be very full in one direction, but must return with very light loads to recycle. Designing routes to serve important nodes on both ends will generally improve productivity.

Things you need to know for this exercise:

1. Ridership on Route 96 has been growing, as first revealed by daily farebox passenger boarding figures.
2. The route has also developed a problem with keeping on schedule. The early warning for this is usually declining on-time performance figures. An even more accurate warning may come from the drivers, who let management know they are having trouble keeping the schedule during certain times of the day due to insufficient running time and heavy boardings at several locations.

The maximum load point (max point for short) has been determined over time for this route from ride checks (see the discussion in Chapter 2, Inputs to the Scheduling Process, about ride check analysis). It is at a major intersection, Pasco & Havre, which is also a time point and a fairly sizable transfer point. Route 96 has changed character over the years, from a route with a very pronounced peak direction to one where ridership is generally well balanced in both directions during peak periods. This trend has been beneficial in making better use of scheduled trips during peaks: previously non-peak-direction trips operated with few passengers but now trips carry good loads in both directions during the peak period. The route has also seen a reduction in peak loads in the peak direction, allowing a slightly wider headway to carry similar numbers of riders per trip.

Analysis of trips by time periods provides a sense of how well demand (riders) meets supply (seats plus standees). Schedule departments have traditionally used analysis periods of 15- to 30-minute intervals during times when headways are 10 minutes or less and 30- to 60-minute intervals during times when headways are 15 minutes or more. The load average spreadsheet for Route 96 is shown on the following page.

The load average spreadsheet has thicker lines at hourly intervals during the base and half hourly intervals during the two peaks. We use the scheduled arrival time at the max point (the “due” column, second from the left) to determine where trips fit in the time breaks. The load analysis examines each time interval. The spreadsheet also contains formulas in each time interval: the first sums all passengers observed (this check collected the maximum number of passengers, whether that was the arriving load or the leaving load); the second calculates the average load per trip within the time interval. Average load per trip within the time interval is shown in bold on the load average spreadsheet.

SAMPLE TRANSIT AGENCY

AVERAGED MAX LOAD POINT CHECKS

ROUTE 96 - PASCO AVENUE　WEEKDAY　SCHED NO. 5　SOUTHBOUND

PASCO & HAVRE　ARRIVING LOAD

		Tuesday April 1			Thursday April 10			Wednesday May 7			
		Sunny 47 degrees			Cloudy, rain, 54 degrees			Overcast, cool, 57 degrees			
BLK	DUE	ACTUAL	LOAD	Tot/Avg	ACTUAL	LOAD	Tot/Avg	ACTUAL	LOAD	Tot/Avg	AVERAGE
5	6:07	6:08	11		6:09	14		6:06	12		
9	6:22	6:23	27		6:22	30		6:22	26		
1	6:37	6:37	22	88	6:38	24	97	6:39	23	87	
6	6:52	6:51	28	22	6:55	29	24	6:53	26	22	23
3	7:10	7:10	33	69	7:09	35	70	7:12	31	64	
7	7:25	7:26	36	35	7:26	35	35	7:26	33	32	34
8	7:35	7:36	38		7:38	37		7:37	39		
4	7:45	7:42	41	123	7:46	43	126	7:46	40	121	
5	7:55	7:58	44	41	7:58	46	42	7:58	42	40	41
9	8:05	8:07	40		8:05	43		8:06	41		
1	8:15	8:16	42	120	8:16	43	126	8:15	40	117	
6	8:25	8:27	38	40	8:28	40	42	8:24	36	39	40
10	8:35	8:35	36		8:35	37		8:37	33		
2	8:45	8:46	32	102	8:45	35	104	8:46	33	96	
3	8:55	8:57	34	34	8:56	32	35	8:55	30	32	34
7	9:05	9:04	27		9:06	33		9:05	30		
8	9:15	9:26	40		9:15	27		9:16	25		
4	9:27	9:27	14		9:28	26		9:28	24		
5	9:38	9:41	23	130	9:40	24	132	9:41	21	124	
6	9:53	9:54	26	26	9:55	22	26	9:53	24	25	26
1	10:08	10:07	21		10:08	23		10:08	22		
2	10:23	10:23	19		10:24	22		10:25	20		
3	10:38	10:37	22	80	10:37	23	90	10:40	23	83	
4	10:53	10:55	18	20	10:53	22	23	10:54	18	21	21
5	11:08	11:08	24		11:10	29		11:08	27		
6	11:23	11:25	26		11:23	24		11:23	25		
1	11:38	11:37	25	101	11:39	25	106	11:38	24	102	
2	11:53	11:53	26	25	11:58	28	27	11:55	26	26	26
3	12:08	12:08	23		12:09	25		12:09	26		
4	12:23	12:24	25		12:20	15		12:24	27		
5	12:38	12:40	24	100	12:38	36	105	12:38	23	104	
6	12:53	12:54	28	25	12:54	29	26	12:53	28	26	26
1	13:08	13:08	28		13:08	30		13:08	29		
2	13:23	13:23	27		13:24	29		13:24	26		
3	13:38	13:39	32	106	13:39	31	115	13:39	29	106	
4	13:52	13:50	19	27	13:53	25	29	13:54	22	27	27
5	14:07	14:07	33		14:08	35		14:09	32		
6	14:22	14:24	28		14:22	32		14:22	28		
1	14:37	14:34	22	110	14:37	33	136	14:40	29	121	
2	14:52	14:50	27	28	14:55	36	34	14:53	32	30	31
3	15:07	15:07	29		15:07	31		15:06	30		
4	15:22	15:22	28		15:22	30		15:23	29		
5	15:37	15:39	31	120	15:36	32	127	15:37	27	116	
14	15:50	15:53	32	30	15:50	34	32	15:54	30	29	30
6	16:02	16:01	36		16:04	38		16:04	35		
1	16:14	16:15	34	109	16:15	37	116	16:14	29	97	
2	16:26	16:28	39	36	16:28	41	39	16:27	33	32	36
3	16:39	16:41	38		16:38	40		16:41	42		
4	16:49	16:49	43	128	16:50	46	135	16:51	44	136	
12	16:59	17:01	47	43	17:00	49	45	17:00	50	45	44
5	17:09	17:13	51		17:10	55		17:09	54		
13	17:19	17:22	53	153	17:21	58	166	17:20	56	164	
14	17:29	17:32	49	51	17:31	53	55	17:33	54	55	54
6	17:39	17:43	44		17:42	48		17:41	49		
1	17:48	17:48	39	118	17:48	40	130	17:47	41	127	
11	17:58	17:58	35	39	17:58	42	43	17:58	37	42	42
3	18:10	18:11	30		18:10	37		18:11	33		
2	18:23	18:24	27		18:25	32		18:25	30		
4	18:38	18:39	29	110	18:39	30	127	18:39	26	118	
13	18:53	18:53	24	28	18:53	28	32	18:54	29	30	30
14	19:06	19:07	20		19:09	28		19:06	24		
6	19:21	19:20	18	53	19:22	20	68	19:22	19	60	
1	19:41	19:41	15	18	19:42	20	23	19:41	17	20	20
2	20:01	20:02	19		20:01	22		20:02	20		
13	20:21	20:21	12	47	20:23	16	56	20:21	15	54	
14	20:41	20:40	16	16	20:40	18	19	20:43	19	18	17
1	21:01	21:01	11		21:01	15		21:00	12		
2	21:18	21:19	9		21:18	12		21:18	14		
13	21:38	21:39	14	44	21:42	13	51	21:39	11	49	
14	22:01	22:01	10	11	21:59	11	13	21:59	12	12	12

Peaks of the peak loads

peak of the peak

The absolute busiest time interval (measured in short increments such as 15 or 30 minutes, depending on headway) during the peak period, in terms of passenger demand and service.

Tip Even if you have the resources for trip-by-trip analysis, traffic check data should be averaged over a time interval of three to four times the headway. Loading on individual trips varies greatly, while loading over a time period remains fairly constant.

Route 96 operates past the maximum load point every 15 minutes during the base period and every 10 during the peaks. So the peak periods are divided into 30-minute intervals and the base period into 60-minute intervals.

The time interval is critical. We do not want to miss the high peak of the peak loads by averaging these with too many trips on either side (in the shoulders of the peak). We cannot always schedule effectively for the peak of the peak demand, but averaging trips that are too far away from the peak of the peak can give us a false lower estimation of peak demand. Use of a 30-minute interval during the peak periods avoids this pitfall on Route 96.

Keep in mind the overall purpose, which is to be able to compare observed loads against established service standards. Looking at individual trip loadings is too precise for analysis when service is this frequent, as trips can run erratically due to traffic and other factors largely out of the control of the transit system. These factors can produce overloads on one trip while surrounding trips are running with fewer passengers than normal. Bus operators also vary as to style of driving. Some are faster than others, meaning they are able to handle the business of collecting fares, handing out information, tying down wheelchairs, and maneuvering through traffic better than their fellow operators. The averaging process within the analysis period helps to compensate for these differences.

The average load spreadsheet is laid out to accommodate three separate days' checks. We could add or subtract columns based on the number of days of data available. As always, more than one day of data is recommended for any schedule analysis.

For this example, we concentrate on the maximum load point of the route for data collection. Route 96 has two branches, designated 96 and 96A on the driver's route map, although 96A may not appear on public timetables or bus headsigns.[1] A thorough review of ridership would also call for a point check at the junction of these two branches, at the time point of Pasco & Essex. The existing schedule is built with all trips alternating between each branch throughout the day. This is the most practical arrangement when route branches exist, but it does not mean that ridership justifies this equal distribution of service. One branch could be significantly weaker and only justify, say, one out of three trips. Since the balance of ridership between the two branches usually does not change much over time, it is not necessary to schedule point checks at this location on a regular basis. For the purpose of this exercise, ridership on each branch is assumed to be roughly equal and checks made at Pasco & Essex have shown very little shift over the past several years.

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[1] Schedules material will often contain notations for operating personnel—including telephone information for customer service representatives—that do not appear on written public materials. Identifying the branch of a route (such as the 96A in our example) for operational purposes, but not for the public, is not uncommon.

With all load numbers laid out conveniently on this sheet, it is easy to see the dimensions of the peak. During the AM peak in the southbound direction, service levels are adequate. On average, there are two to three standees per trip between 7:30 and 8:00 AM (average load is 41) and between 8:00 and 8:30 AM (average load is 40). We would then want to look at the northbound direction loads, the known peak direction, before making any judgment on service adjustments.

In the PM, it is a different situation. For the 17:00-17:30 peak half hour, the average load is 53, five higher than the standard allows. The time periods before and after this period show averages of 42 and 44, respectively, which are within the standard. An additional trip is needed in this half-hour period in order to bring the loads down to within the maximum specified in the standard (48). A simple calculation shows that a fourth trip during this half hour would bring the average load down to slightly more than 39. Since the neighboring time intervals could benefit from the added trip, we would extend the reduced headway for more than just the peak half-hour period.

It is a good idea to sketch any potential change to see what the proposed schedule might look like. Here is an initial proposal for fixing the overload period:

Southbound times at the max point (Pasco & Havre):

Present	Proposed
16:39	16:39
16:49	16:48
16:59	16:56
	17:04
17:09	17:12
17:19	17:20
17:29	17:28
17:39	17:37
17:48	17:47

This particular adjustment spreads the benefit of the additional trip over an approximate 40- minute period, which helps to lower the peak count on six trips. What other effects does this have on the schedule? The scheduler knows that the layover at both ends of the route is already tight, so it is unlikely that this extra trip can be provided using the existing number of buses. But it is too early in the process to finalize this change. The scheduler also noted that

Tip The amount of data available for analysis will depend both on the number of days of checking and on the schedule used to deploy traffic checkers. Traffic checking shifts can be scheduled in different ways. A typical checking assignment will cover a location for 16 straight hours with two shifts, often 5:00 AM to 9:00 PM or 6:00 AM to 10:00 PM. These shifts cover the times when there is usually the greatest need to observe loads and trip performance. At times there may be a need to look at the ends of the service day. In this case, a “start to finish” schedule, which will typically leave a portion of the middle of the day uncovered, can be used. For Route 96, the early checker would be in place at Pasco & Havre at about 4:25 AM and remain there until 12:25 PM. The afternoon checker would be assigned there at least by 4:30 PM and remain there until the last trip, a northbound bus, passes at 12:26 AM. Combining both of these types of checks together provides the whole picture on max point ridership.

One final point on scheduling traffic checks is that checkers, like all employees, will need breaks for meal times and rest periods. Checking over multiple days can allow checker breaks to occur at different times on different days, ensuring that there are no significant gaps in data collection.

passengers per-minute

or PPM for short, is the measurement of how many people accumulate every minute at all bus stops waiting for service in the direction being analyzed. It is generally expressed as a decimal number, such as 5.8 PPM. What that means is that, between the time the last trip departed and the next trip is at the stop, 5.8 potential customers arrive at this bus stop every minute. That number helps tell us how much service we need to run to meet the demand within our service standard.

most of the trips in the peak, as well as during other times in the operating day, seem to be arriving late. A running time analysis is appropriate before crafting a final change proposal.

Before analyzing the running time, the scheduler needs to examine the base and evening periods. Different standards are provided for those periods. During the base, the agency's standards call for a minimum 50% load during the midday period and all day on Saturday. This guideline is meant to allow for a better base service frequency, which is expected to attract more riders. That translates to a half seated load of at least 19 on each trip. The hourly time analyses between 9:00 AM and 4:00 PM (16:00) all exceed that, ranging from 21 to a high of 30 just before the shoulder of the PM peak. The scheduler could actually look at the effect of adding some base service. The **passengers per-minute** (PPM) calculation helps here, providing a quick way of performing a what-if analysis.

How is the PPM figure calculated? The following example using the average loads of the three ridechecks on Route 96 illustrates the calculation during the peak of the peak just after 5:00 PM.

Trip Arrive	Load	Minutes since last trip	Trip PPM	Minutes since 16:49	Period PPM
16:49		0		0	
16:59	49	10	4.90	10	4.90
17:09	53	10	5.30	20	5.10
17:19	56	10	5.60	30	5.27
17:29	52	10	5.20	40	5.23
Total	214				

How many passengers should be on each bus? If the service standards call for a seated load plus a 25% standee rate during the peak period (a common standard) and the buses assigned to this route seat 38, then each trip should be scheduled to carry a maximum of 48 passengers past the max point. In this example, all four trips exceed a load of 48. At 4.9 PPM for the 16:59 trip, if the bus were only one minute earlier, there would be 44 instead of 49 patrons on board.

Since the PPM can be highly volatile, especially when the service is running erratically, it is easier to "smooth" out the calculation by looking at a number of trips over time. For the entire

40-minute time period we have analyzed, the PPM is 5.23. Divided into a 48 minute cycle time, we find that a nine-minute headway would provide the service level we are looking for.

It is also useful if we decide to adjust loads on our sheet to account for early and late trips. To keep our discussion of max point analysis a bit simpler, we will "eyeball" the early or late trips, their corresponding loads, and mentally make adjustments as we record averages by time period. This practice is certainly acceptable provided that we know our route and a little about what causes early or late operation. If the max load numbers are accurate (and they are by this point), then our judgment should not cause us to err significantly in producing a representative average for the time period.

We can take the noon hour, where the average load is 26 and calculate what would happen if we went from four to five buses per hour (a 12-minute headway on the trunk portion of the route). We have a three-day average of 103 passengers over a 60-minute time period, which yields a PPM of 1.72. Multiplying that number by 12 (the new headway) gives us 21, the number of average passengers on-board for the improved service. Since our goal is to have no fewer than 19 on board, a 12-minute headway would meet our goal.

We know we need to add PM peak service and we could also add some service in the base, but the base addition is discretionary. The current average load of 26 represents only 68% of the seats filled and no standees. The following considerations will influence the decision:

- Can the agency afford the additional 6-12 platform hours that one or two added buses would cost us?
- Does the ridership trend in the base on this route continue to show growth?
- Is the average load in any of the time periods approaching a seated load?
- Is the peak-to-base ratio on this route high enough to justify more base service in order to help produce a more economical runcut?

The last two points are the most germane in helping to make the decision. The average loads are not high enough to be a concern at this point and the peak-to-base ratio is still reasonable (six base buses compared with 10 during the peak, giving a ratio of 1.67). Anything below a ratio of 2.00 will produce a reasonably cost-efficient runcut in most situations. (More on what makes a runcut cost-efficient is presented in Chapter 5.)

The decision, then, is to adjust the PM peak service to address the overloads and leave the base period alone for now. The next step is analyzing running time.

Tip When planning peak hour service, it is often useful to have standards that reflect the maximum number of people that should be on board the bus at the maximum load point. Higher loads will result in increased service. For off-peak service, including evenings and weekends, it is useful to have both maximum load standards and standards that reflect the minimum number of passengers that should be on board before service is reduced.

Running Time Checks

Running time is even more volatile than passenger loads since it depends on street conditions, and individual driver habits. To account for variations in running time, schedulers should err on the side of having more checks available to analyze. Ride checks can be taken continuously throughout the system and, like point checks, can be supplemented with regular discussions with drivers and other operating personnel who are known to give accurate feedback.

The early warning mechanism in this example is noting that a number of the trips on Route 96 showed up late at the maximum load point. Also, there were no more than a handful of early trips, which is an indicator that running time sufficiency needs to be reviewed. For this purpose, the scheduler once again turns to a three-day check summary. The most efficient way of obtaining a multi-day summary of running time data is from automated data collection methods, such as APCs or an AVL system. But not all transit properties have APCs or have plans to procure them in the near future.

What are the best manual methods of spreading and calculating running times? There are two basic steps in this task. First is the analysis of individual checks. This includes a review of the check itself for normalcy of operation and for possible hand adjustment to account for any slightly erratic operation so that the times will reflect what would be considered the “normal case” if the aberrations were removed.

Once the “normal” or “representative” checks are accumulated and the “outlier” checks have been discarded, the second step is to post the times to a comparison sheet where the multiple days’ checks can be readily studied and averaged. The example on page 3-39 shows a portion of an expanded headway sheet that could be marked up manually or filled in electronically, complete with formulas to average the several days’ observed running times. These times have been analyzed beforehand, so no additional notations or allowances need to be made.

The spreadsheet has two columns beside the observed running time totals that show the present running time period breaks and the scheduled running time. The bold horizontal lines mark the beginning and end of periods for which running times will be averaged. Three-day averages of running times for each trip in each direction are shown in the columns to the right of the northbound and southbound schedules. Next, the recommended (or “decided”) running times for a given time period are displayed.

Establishing Running Time Periods

There are two separate steps in analyzing running time:

1. Break the operating day down into individual running time periods for each direction
2. Analyze and adjust the individual running times between time points so they add up to the total for the one-way trip.

Running time periods, also called “classes,” “breaks,” and “levels” at various systems, are times of the day when a specific running time is in effect. The number for each schedule can vary from one running time period for the entire day to 20 or more. They are established or adjusted by looking at trends in how total trip running times vary over the day. Total one-way running times have traditionally been used to find where these breaks occur, as the individual times between time points provide too much information to digest and consider manually. Computerized scheduling packages simplify the adjustment of running times by segment.

We begin by looking at the total running time for each trip in each direction. We are trying to spot trends. Running times tend to jump around a bit. In the example below, note that even with the variances you can see when the trend is moving upward or downward.

Trip	Total Time
5:06	42
5:26	44
5:40	43
5:55	46
6:10	49
6:20	48
6:20	51
6:40	49
6:50	50
7:00	53
7:10	55
7:20	54
7:30	56
7:40	55
7:50	54
8:00	55
8:10	53
8:20	51
8:35	49
8:50	48
9:05	50
9:25	47
9:45	46
10:05	47

The figures represent total trip times during the early morning, AM peak, and mid morning base periods. On first glance, it looks as if there is no order at all to totals, much less a trend. But experience suggests that even with some slight variations among adjacent trips, the trend should be for increases during the buildup to the 8:00 AM peak-of-the-peak and decreases afterward.

The first three trips are all within a minute of an average 43 minutes of running time. The running time for the fourth trip at 5:55 is notably higher, so a time break before the 5:55 trip is appropriate. Likewise, there is a similarity in running times between 7:00 and 8:10. The times range between 53 and 56 minutes and average 54.4 minutes. Toward the end of the table in the base period, running time is in the 46 to 47 minute range. The average of the last three trips on our table is 47. Thus, we have dealt with the easier-to-spot areas first.

Between the early trips and the peak and between the peak and the base are transition areas. Times either ramp up or down relatively quickly. The question is: how big is the gap between the highest peak number and the lowest early or base number? Can one transitional running time bridge the gap or is the difference large enough to require two or more running time periods?

Following is the same table of trip times sliced into different running time periods using the method just described.

Trip	Total Time	Average
5:06	42	
5:26	44	43
5:40	43	
5:55	46	
6:10	49	
6:20	48	
6:20	51	48.8
6:40	49	
6:50	50	
7:00	53	
7:10	55	
7:20	54	
7:30	56	54.4
7:40	55	
7:50	54	
8:00	55	
8:10	53	
8:20	51	
8:35	49	49.5
8:50	48	
9:05	50	
9:25	47	
9:45	46	47
10:05	47	

The transition period from the early AM to the AM peak must help bridge an increase of 11 minutes. Analysis of the actual trip times shows a range from 46 to 51 minutes during the transition period between 5:55 and 6:50. The average of all six trips is 48.8 rounded to 49, about halfway between the adjacent averages. In this case, the decision is to go with the 49 and just one transition running time period.

An alternate but equally reasonable choice would have been to divide the period into two three-trip periods. Under this option, the first three trips average 47, while the second three average 50. The result would be two transitional running time periods and a better smoothing (in terms of less headway variation) of the running time transitions. Either one or two transition running time periods is acceptable, so long as the scheduler plans to perform manual smoothing of the trips to keep headways as close to 10 minutes as possible.

The second transition, into the base, is less dramatic, having a difference of only seven minutes. One transitional running time period should suffice here and the times average 50, which is just about halfway between the two times. A similar effort, not shown here, is needed going into and out of the PM peak. From the PM peak into the night running time, two transition periods might be needed because of the large drop in running time.

This same principle applies to our large running time summary sheet for Route 96. The first step is to “eyeball” the totals on the sheet, looking especially at the peaks and valleys during the day. Then group similar running time totals into periods. Laying out individual running time observations this way provides an ideal way of looking at trends. As noted earlier, the spreadsheet has two columns beside the observed running time totals that show the present running time period breaks and the scheduled running time. Working on the computer or on hard copies of these sheets, the scheduler can make notations about any needed changes , both to the time when running time periods change and to new, proposed totals. Note again that the scheduler works first with totals and then works backwards to adjust the individual running times.

The analysis of the AM peak generally shows the present running times are adequate. Individual times on trips and trip segments do vary, but over the full period of the peak, actual running times are very close to scheduled running times for each branch in both the northbound and southbound directions. The same holds true of the base.

HEADWAY SHEET

Line 96
MONDAY THRU FRIDAY

IN EFF: September 15, 2007

HEADWAY WITH 3-DAY RUNNING TIME CHECKS ADDED

DIRECTION = NORTH - SOUTH
AM

Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle	Avg Lib/Wsh	Avg Sand Pt	Proposed Lib/Wsh	Proposed Sand Pt	Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	IN GAR	Avg Lib/Wsh	Avg Sand Pt	Proposed Sand Pt	Proposed Lib/Wsh
5:05		5:19	5:29	5:37	5:46					5:50	5:59	6:07	6:17		6:27					
	5:19	5:29	5:39	5:47	5:56					6:05	6:14	6:22	6:32	6:42						
											9.5	8	9	10						
											10	7.5	9.5	9						
											9	7.5	10	9						
											9.5	7.67	9.5	9.33			36			
5:35		5:49	5:59	6:07	6:16					6:20	6:29	6:37	6:47		6:57				37	37
											9	8	10		9.5					
											8.5	8.5	9.5		9.5					
											9.5	8	11		10					
											9	8.17	10.2		9.67			37		
	5:49	5:59	6:09	6:17	6:26					6:35	6:44	6:52	7:02	7:12						
								41	37		9.5	8	10	10						
											8.5	9	9.5	9.5						
											9.5	9	9.5	9.5						
											9.17	8.67	9.67	9.67			37			
6:05		6:19	6:29	6:37	6:46					6:50	7:01	7:10	7:21		7:32					
	14		9.5	8	9.5						10	9	10		11					
	13		9.5	8.5	9.5						10.5	9.5	11		11.5					
	13.5		10	8	9						10.5	9.5	11		10.5					
	13.5		9.67	8.17	9.33	41					10.3	9.33	10.7		11			41		
	6:19	6:29	6:39	6:47	6:56					7:05	7:16	7:25	7:36	7:46						
		10	9.5	8.5	9						11	9	10	10						
		10	10	9	9.5						10.5	8.5	11	9						
		9.5	10.5	8.5	9.5						10.5	9	11.5	12						
		9.83	10	8.67	9.33		38				10.7	8.83	10.8	10.3			41			
6:25		6:39	6:50	6:59	7:10					7:15	7:26	7:35	7:46		7:57					
	13		12	9	10						11.5	9	11		11					
	14		11	8	11						11	9	12		10					
	14		11	9	12						11	8	11		10					
	13.7		11.3	8.67	11	45					11.2	8.67	11.3		10.3			42		
	6:37	6:49	7:00	7:09	7:20					7:25	7:36	7:45	7:56	8:06						
		11	12	9	11						11	9	11	10					41	42
		12	11	9	12						12	9	10	10						
		12	12	8	11						11	10	11	11						
		11.7	11.7	8.67	11.3		43				11.3	9.33	10.7	10.3			42			
6:45		6:59	7:10	7:19	7:30					7:35	7:46	7:55	8:06		8:17					
	14		11	9	12						11	9	12		11					
	14		11	10	11						11	9	11		12					
	15		11	9	11						12	10	11		11					
	14.3		11	9.33	11.3	46					11.3	9.33	11.3		11.3			43		
	6:57	7:09	7:20	7:29	7:40					7:45	7:56	8:05	8:16	8:26		8:46				
		12	11	9	11						10	9	11	10						
		13	10	8	11			45	43		11	8	10	11						
		11	11	9	12						11	9	11	11						

A look at the PM peak shows the inadequacy noted earlier based on the analysis of the passenger load checks at the max point. More than a few trips arrived late at Pasco & Havre by one or two minutes. At the same time, overcrowding was seen on southbound trips during the height of the PM peak. These two trends suggest the need to rebuild the PM portion of the schedule.

HEADWAY SHEET

Line 96
MONDAY THRU FRIDAY

IN EFF: September 15, 2007

HEADWAY WITH 3-DAY RUNNING TIME CHECKS ADDED

DIRECTION = NORTH - SOUTH

PM PEAK PERIOD

Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle	Avg Lib/Wsh	Avg Sand Pt	Proposed Lib/Wsh	Proposed Sand Pt	Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	LVE.	Avg Lib/Wsh	Avg Sand Pt	Proposed Sand Pt	Proposed Lib/Wsh
15:35		15:48	15:59	16:06	16:16					16:20	16:31	16:39	16:50	17:01		17:05				
	13		12	7	10						12	9	12	12						
	12		11	7	11						12	9	11	12						
	13		12	7	10						13	8	12	13						
	12.7		11.7	7	10.3	42					12.3	8.67	11.7	12.3			45			
	15:48	15:58	16:09	16:16	16:26					16:30	16:41	16:49	17:00		17:12	17:15				
		11	11	7	10						13	9	13		13				45	46
		10	11	8	9						12	8	12		13					
		11	10	8	10						11	9	12		13					
		10.7	10.7	7.67	9.67		39				12	8.67	12.3		13			46		
		16:08	16:19	16:26	16:36					16:40	16:51	16:59	17:10	17:21		17:28				
			12	7	10						12	9	12	12						
			11	7	11						13	9	12	13						
			11	8	10						12	8	11	13						
			11.3	7.33	10.3		29				12.3	8.67	11.7	12.7			45			
16:05		16:18	16:29	16:36	16:46					16:50	17:01	17:09	17:20		17:32	17:36				
	13		12	7	10						12	8	12		13					
	13		11	8	10						12	9	13		14					
	14		12	8	10						11	8	12		13					
	13.3		11.7	7.67	10	43					11.7	8.33	12.3		13.3			46		
	16:15	16:25	16:36	16:44	16:55					17:00	17:11	17:19	17:30	17:41		17:53				
		11	12	8	10						12	8	12	12						
		11	12	8	11			45	42		11	9	13	12						
		10	11	9	11						13	9	12	11						
		10.7	11.7	8.33	10.7		41				12	8.67	12.3	11.7			45			
		16:35	16:46	16:54	17:05					17:10	17:21	17:29	17:40		17:52	18:05				
			12	8	11						12	9	12		13					
			12	8	10						12	8	11		13				45	46
			12	7	11						13	8	12		14					
			12	7.67	10.7		30				12.3	8.33	11.7		13.3			46		
16:32		16:45	16:56	17:04	17:15					17:20	17:31	17:39	17:50	18:01						
	14		12	8	11						12	9	11	13						
	13		11	7	12						13	8	12	12						
	13		11	7	11						12	8	12	11						
	13.3		11.3	7.33	11.3	43					12.3	8.33	11.7	12			44			
	16:45	16:55	17:06	17:14	17:25					17:30	17:40	17:48	17:58		18:10	18:35				
		11	11	7	11			45	42		12	8	11		13					
		11	12	8	11						12	9	12		12					
		11	12	8	10						11	8	11		11					
		11	11.7	7.67	10.7		41				11.7	8.33	11.3		12			43		

A sketch of proposed headway changes (refer back to page 43) indicated that an eight-minute headway in the peak of the peak would meet the load standard. The tables below show a comparison of present versus proposed adjusted running times. On these tables, the start time of the first trip with a change in running time is highlighted in gray to allow the reader to refer back to the original schedule.

NORTHBOUND

Current Runtimes			Proposed Runtimes		
Period Beginning	**Wishram**	**Sand Point**	**Period Beginning**	**Wishram**	**Sand Point**
4:00	36	32	4:00	36	32
5:05	41	37	5:05	41	37
6:25	45	43	6:25	45	43
8:23	41	39	8:23	41	39
8:53	39	38	8:53	39	38
9:23	39	36	9:23	39	36
13:35	41	38	13:35	41	38
16:15	43	40	16:15	45	42
17:36	39	36	17:36	39	36
19:53	33	31	19:53	33	31

Southbound

Current Runtimes				Proposed Runtimes		
Period Beginning	Wishram	Sand Point		Period Beginning	Wishram	Sand Point
4:10	33	32		4:10	33	32
5:20	37	37		5:20	37	37
6:50	42	41		6:50	42	41
9:22	37	36		9:22	37	36
13:35	39	38		13:35	40	39
				15:33	43	42
16:20	42	41		16:20	46	45
17:30	40	39		17:30	42	41
18:50	36	35		18:50	37	36
21:05	31	30		21:05	31	30

Clearly, the southbound direction running time gets the biggest adjustment. In the PM peak four minutes will be added to both branches over the present allowances. In contrast, only minor changes are made to the 16:15 peak running time period in the northbound direction. An additional running time period (from 15:33 to 16:20) is added in the southbound direction, both in order to help ramp up running times smoothly and because added running time is needed that early in the PM. There is an additional running time after the PM peak when running times are dropping by as much as 6 minutes per period. Experience has shown that it is relatively easy to smooth out the running time transition, since the headway will be widening throughout that time as well.

In the advanced section, you will take these changes and incorporate them into a fully revised Route 96 schedule, with new running times that differ throughout the day and adjusted headways to meet demand.

LEVEL 2B

End of Intermediate Schedule Building, Part B.

The Advanced Section of Schedule Building continues on the next page.

To jump to Schedule Blocking, go to page 4-1.

3.4 Advanced Schedule Building—Adjusting a More Complex Schedule Based on Check Data

LEVEL 3A

Schedulers are often in the position where minor changes need to be made to existing schedules. The previous section showed how to analyze traffic check data to find instances where the present schedule is no longer functioning properly. In the case of Route 96, both the ridership and running time have increased beyond the ability of the schedule to properly do its job.

The scope of change is clear from the preceding section: additional running time is needed in the PM peak and an additional trip is also needed to bring loads down within prescribed standards. The change will require at least one additional bus, because the layover in the present schedule is as tight as possible. The first step is to calculate the new round trip cycle with the additional running time to see what effect this will have on the bus count. The second step is to change the headway from 10 to 8 minutes in the peak of the PM peak.

The longest round trip running time (using the longest branch, 96 to Libby & Wishram as we did the first time) is now 46 + 43 = 89 minutes. We are presently scheduling a 10-minute interval/headway. If we were to continue to use nine buses, it would give us a 90-minute cycle (9 buses x 10-minute headway). So even without the addition of a trip to achieve eight minute service in the peak of the peak, the additional running time leaves insufficient layover on several trips. The example below tries unsuccessfully to fit the new running times into the existing schedule.   Several southbound trips (highlighted in gray) have either no layover or negative layover time, and layover time on northbound trips is too tight to adjust.

SCHEDULE SHEET - Revised running times in original schedule

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

NORTHBOUND									SOUTHBOUND								
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	IN GAR	LVE.
2			15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52		16:52
3		15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05			17:05
4			15:48	15:58	16:09	16:16	16:26		16:30	16:42	16:51	17:03		17:16		17:15
11	15:53			16:08	16:19	16:26	16:36		16:40	16:52	17:01	17:13	17:25			17:28
5		16:05		16:18	16:29	16:36	16:46		16:50	17:02	17:11	17:23		17:36		17:36
12			16:15	16:25	16:36	16:44	16:55		17:00	17:12	17:21	17:33	17:45			17:53
13	16:20			16:35	16:46	16:54	17:05		17:10	17:22	17:31	17:43		17:56		18:05
6		16:32		16:46	16:58	17:06	17:17		17:20	17:32	17:41	17:53	18:05		18:25	
1			16:45	16:56	17:08	17:16	17:27		17:30	17:41	17:49	18:00		18:12		18:35
2		16:52		17:06	17:18	17:26	17:37		17:40	17:51	17:59	18:10	18:21			18:23
3			17:05	17:16	17:28	17:36	17:47		17:52	18:03	18:11	18:22		18:34	18:54	
4		17:15		17:29	17:41	17:49	18:00		18:05	18:16	18:24	18:35	18:46			18:53
11			17:28	17:39	17:51	17:59	18:10								18:20	

Adding a tenth bus results in a 100-minute cycle (10 x 10), which is achievable for the existing 10-minute headway. The goal is to keep the southbound headway as even as possible. In the spreadsheet, the leaving times of all trips which will need their running time adjusted are highlighted. Running time periods with revised times southbound begin at 13:30 and extend to just before 21:00. New northbound running times are needed beginning at 16:15 and extending until 17:36. Choose the leaving times of these trips and highlight them in gray, as shown below.

SCHEDULE SHEET with trips needing new times highlighted

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

NORTHBOUND								SOUTHBOUND							
OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	IN GAR	LVE.
		12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:13			14:23
	13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:29		14:35
		13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:43			14:53
	13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		14:59		15:05
		13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:13			15:23
	14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:29		15:35
		14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:43			15:48
	14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		15:59		16:05
15:23								15:33	15:43	15:50	16:01	16:11			16:15
		14:53	15:03	15:14	15:21	15:31		15:45	15:55	16:02	16:13		16:24		16:32
	15:05		15:18	15:29	15:36	15:46		15:57	16:07	16:14	16:25	16:35			16:45
		15:23	15:33	15:44	15:51	16:01		16:09	16:19	16:26	16:37		16:48		16:52
	15:35		15:48	15:59	16:06	16:16		16:20	16:31	16:39	16:50	17:01			17:05
		15:48	15:58	16:09	16:16	16:26		16:30	16:41	16:49	17:00		17:12		17:15
15:53			16:08	16:19	16:26	16:36		16:40	16:51	16:59	17:10	17:21			17:28
	16:05		16:18	16:29	16:36	16:46		16:50	17:01	17:09	17:20		17:32		17:36
		16:15	16:25	16:36	16:44	16:55		17:00	17:11	17:19	17:30	17:41			17:53
16:20			16:35	16:46	16:54	17:05		17:10	17:21	17:29	17:40		17:52		18:05
	16:32		16:45	16:56	17:04	17:15		17:20	17:31	17:39	17:50	18:01		18:21	
		16:45	16:55	17:06	17:14	17:25		17:30	17:40	17:48	17:58		18:10		18:35
	16:52		17:05	17:16	17:24	17:35		17:40	17:50	17:58	18:08	18:19			18:23
		17:05	17:15	17:26	17:34	17:45		17:52	18:02	18:10	18:20		18:32	18:52	
	17:15		17:28	17:39	17:47	17:58		18:05	18:15	18:23	18:33	18:44			18:53
		17:28	17:38	17:49	17:57	18:08								18:18	
	17:36		17:49	17:59	18:06	18:15		18:20	18:30	18:38	18:48		19:00		19:05
		17:53	18:03	18:13	18:20	18:29		18:35	18:45	18:53	19:03	19:14			19:23
	18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:15		19:26		19:35
		18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:30	19:40			19:53
	18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:50		20:01		20:06
		18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:10	20:20			20:28
	19:05		19:18	19:28	19:35	19:44								19:54	
		19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:30		20:41		20:46
	19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:50	21:00			21:08
		19:53	20:03	20:12	20:19	20:26								20:36	
	20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:10		21:21		21:26

Next, apply the new running times for these trips. Once the southbound trips are adjusted, do the same thing for the northbound direction. Northbound there is only one period that has changed, the 16:15 period, which encompasses trips leaving the two outer terminals after the 16:05 trip (at Libby) up to the 17:28 trip leaving Sand Point. The revised schedule reflecting new running times is shown below. Blocks are not shown; the advanced section of the Blocking chapter will show how to reblock this schedule. The spreadsheet shows that there are now four pull-outs in the PM peak, compared to three on the previous schedule: this is the tenth bus required.

Some layovers are tight, especially the 17:50 arrival at Rugby Circle, but this bus will pull in after its next southbound trip.

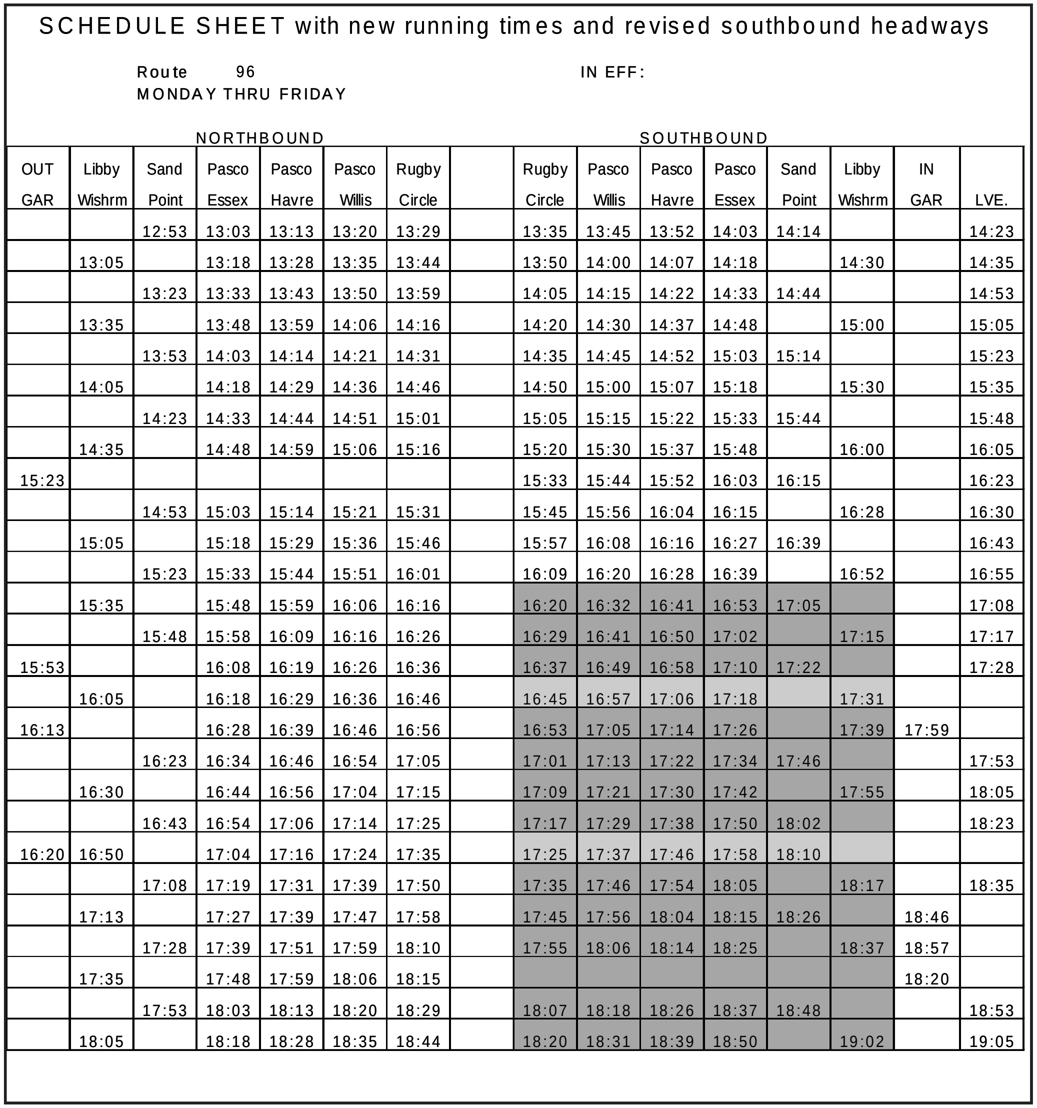
SCHEDULE SHEET with new running times

Route 96 IN EFF:
MONDAY THRU FRIDAY

NORTHBOUND								SOUTHBOUND							
OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	IN GAR	LVE.
		12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:14			14:23
	13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:30		14:35
		13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:44			14:53
	13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		15:00		15:05
		13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14			15:23
	14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30		15:35
		14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44			15:48
	14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00		16:05
15:23								15:33	15:44	15:52	16:03	16:15			16:23
		14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28		16:30
	15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39			16:43
		15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52		17:13
	15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05			17:08
		15:48	15:58	16:09	16:16	16:26		16:30	16:42	16:51	17:03		17:16		17:35
15:53			16:08	16:19	16:26	16:36		16:40	16:52	17:01	17:13	17:25			17:28
	16:05		16:18	16:29	16:36	16:46		16:50	17:02	17:11	17:23		17:36	17:56	
16:13			16:28	16:39	16:46	16:56		17:00	17:12	17:21	17:33	17:45			17:53
		16:23	16:34	16:46	16:54	17:05		17:10	17:22	17:31	17:43		17:56		18:05
	16:30		16:44	16:56	17:04	17:15		17:20	17:32	17:41	17:53	18:05			18:23
		16:43	16:54	17:06	17:14	17:25		17:30	17:41	17:49	18:00		18:12		18:35
16:20	16:50		17:04	17:16	17:24	17:35		17:40	17:51	17:59	18:10	18:21		18:41	
		17:08	17:19	17:31	17:39	17:50		17:52	18:03	18:11	18:22		18:34	18:54	
	17:13		17:27	17:39	17:47	17:58		18:05	18:16	18:24	18:35	18:46			18:53
		17:28	17:39	17:51	17:59	18:10								18:20	
	17:35		17:48	17:59	18:06	18:15		18:20	18:31	18:39	18:50		19:02		19:05

Now that running times have been adjusted, the next step is to reduce peak headways. Adding an additional trip would again bring layover below acceptable levels. Thus, the expectation is that an eleventh bus will be needed to supply the additional southbound trip.

First, add the new PM southbound trips originally sketched into the schedule. It then becomes obvious that the northbound trips will also have to be adjusted to make the new schedule work and all the trips in the PM peak and after will have to be reblocked. Portions of the schedule with headway adjustments are highlighted in dark gray, while added southbound trips are highlighted in light gray.



SCHEDULE SHEET with new running times and revised southbound headways

Route 96 IN EFF:

MONDAY THRU FRIDAY

NORTHBOUND								SOUTHBOUND							
OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	IN GAR	LVE.
		12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:14			14:23
	13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:30		14:35
		13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:44			14:53
	13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		15:00		15:05
		13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14			15:23
	14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30		15:35
		14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44			15:48
	14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00		16:05
15:23								15:33	15:44	15:52	16:03	16:15			16:23
		14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28		16:30
	15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39			16:43
		15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52		16:55
	15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05			17:08
		15:48	15:58	16:09	16:16	16:26		16:29	16:41	16:50	17:02		17:15		17:17
15:53			16:08	16:19	16:26	16:36		16:37	16:49	16:58	17:10	17:22			17:28
	16:05		16:18	16:29	16:36	16:46		16:45	16:57	17:06	17:18		17:31		
16:13			16:28	16:39	16:46	16:56		16:53	17:05	17:14	17:26		17:39	17:59	
		16:23	16:34	16:46	16:54	17:05		17:01	17:13	17:22	17:34	17:46			17:53
	16:30		16:44	16:56	17:04	17:15		17:09	17:21	17:30	17:42		17:55		18:05
		16:43	16:54	17:06	17:14	17:25		17:17	17:29	17:38	17:50	18:02			18:23
16:20	16:50		17:04	17:16	17:24	17:35		17:25	17:37	17:46	17:58	18:10			
		17:08	17:19	17:31	17:39	17:50		17:35	17:46	17:54	18:05		18:17		18:35
	17:13		17:27	17:39	17:47	17:58		17:45	17:56	18:04	18:15	18:26		18:46	
		17:28	17:39	17:51	17:59	18:10		17:55	18:06	18:14	18:25		18:37	18:57	
	17:35		17:48	17:59	18:06	18:15								18:20	
		17:53	18:03	18:13	18:20	18:29		18:07	18:18	18:26	18:37	18:48			18:53
	18:05		18:18	18:28	18:35	18:44		18:20	18:31	18:39	18:50		19:02		19:05

Tip When adding rows or columns to a schedule in a spreadsheet, add only the cells needed and shift the other cells down. Adding whole rows can disturb other information on the spreadsheet, such as the running time table area.

One goal in adding trips was to keep the times at the MLP (Pasco & Havre) to those identified earlier, while working toward an “evenness” in the trip leaving times from Rugby Circle. Evenness means a normal progression of headway narrowing and then widening as times approach the trips that are not being changed. A comparison of current and proposed trip leaving times for the period of change is shown below.

Lvg. Rugby Cir.	
16:09	16:09
16:20	16:20
16:30	16:29
16:40	16:37
	16:45
16:50	16:53
17:00	17:01
17:10	17:09
17:20	17:17
	17:25
17:30	17:35
17:40	17:45
17:52	17:55
18:05	18:07
18:20	18:20

The headway progression is smooth and puts the additional trip where it is needed. Note that two trips have actually been added in order to carry the headway back to the original schedule at 18:20. This has an advantage later on in reblocking the schedule. If only one trip is added to a two-branch route, the trips throughout the remainder of the day would be reversed to each branch.

Now the running time has been adjusted in both directions, and new southbound trips have been added. Study your progress so far. In two cases, two consecutive trips serve the same outer terminal (the 16:45 and 16:53 trips and the 17:17 and 17:25 trips). The solution is to “flip” the terminals until we reach the second added trip, after which the trips again fall to their previous end points. This is shown below, with flipped trips highlighted in dark gray.

SCHEDULE SHEET with new running times and "flipped" southbound trips

Route 96 IN EFF:
MONDAY THRU FRIDAY

NORTHBOUND								SOUTHBOUND							
OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	IN GAR	LVE.
		12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:14			14:23
	13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:30		14:35
		13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:44			14:53
	13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		15:00		15:05
		13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14			15:23
	14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30		15:35
		14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44			15:48
	14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00		16:05
15:23								15:33	15:44	15:52	16:03	16:15			16:23
		14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28		16:30
	15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39			16:43
		15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52		16:55
	15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05			17:08
		15:48	15:58	16:09	16:16	16:26		16:29	16:41	16:50	17:02		17:15		17:17
15:53			16:08	16:19	16:26	16:36		16:37	16:49	16:58	17:10	17:22			17:28
	16:05		16:18	16:29	16:36	16:46		16:45	16:57	17:06	17:18		17:31		
16:13			16:28	16:39	16:46	16:56		16:53	17:05	17:14	17:26	17:38		17:59	
		16:23	16:34	16:46	16:54	17:05		17:01	17:13	17:22	17:34		17:47		17:53
	16:30		16:44	16:56	17:04	17:15		17:09	17:21	17:30	17:42	17:54			18:05
		16:43	16:54	17:06	17:14	17:25		17:17	17:29	17:38	17:50		18:03		18:23
16:20	16:50		17:04	17:16	17:24	17:35		17:25	17:37	17:46	17:58	18:10			
		17:08	17:19	17:31	17:39	17:50		17:35	17:46	17:54	18:05		18:17		18:35
	17:13		17:27	17:39	17:47	17:58		17:45	17:56	18:04	18:15	18:26		18:46	
		17:28	17:39	17:51	17:59	18:10		17:55	18:06	18:14	18:25		18:37	18:57	
	17:35		17:48	17:59	18:06	18:15								18:20	
		17:53	18:03	18:13	18:20	18:29		18:07	18:18	18:26	18:37	18:48			18:53
	18:05		18:18	18:28	18:35	18:44		18:20	18:31	18:39	18:50		19:02		19:05

Tip When adding trips on a route with branches, avoid unintended effects in other time periods. Night service to each branch might be timed to meet the closing time at a shopping center, or riders might simply have learned to depend on specific trip times when headways are at their widest. The ideal solution when working on a two-branch route is to add two trips.

The final step in our schedule adjustment is to add in northbound trips corresponding to the southbound trips already added. Results are shown below, with changed trips highlighted in gray. There are now five PM pullouts, reflecting the addition of the eleventh bus.

SCHEDULE SHEET with adjusted running time and headways

Route 96 IN EFF:
MONDAY THRU FRIDAY

			NORTHBOUND								SOUTHBOUND				
OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	IN GAR	LVE.
		12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:14			14:23
	13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:30		14:35
		13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:44			14:53
	13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		15:00		15:05
		13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14			15:23
	14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30		15:35
		14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44			15:48
	14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00		16:05
15:23								15:33	15:44	15:52	16:03	16:15			16:23
		14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28		16:30
	15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39			16:41
		15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52		16:55
	15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05			17:08
16:19								16:29	16:41	16:50	17:02		17:15		17:17
		15:48	15:58	16:09	16:16	16:26		16:37	16:49	16:58	17:10	17:22			17:28
15:53			16:08	16:19	16:26	16:36		16:45	16:57	17:06	17:18		17:31		17:40
	16:05		16:18	16:29	16:36	16:46		16:53	17:05	17:14	17:26	17:38			17:53
16:11			16:26	16:38	16:46	16:57		17:01	17:13	17:22	17:34		17:47	18:07	
		16:23	16:34	16:46	16:54	17:05		17:09	17:21	17:30	17:42	17:54		18:14	
	16:30		16:44	16:56	17:04	17:15		17:17	17:29	17:38	17:50		18:03		18:05
		16:41	16:52	17:04	17:12	17:23		17:25	17:37	17:46	17:58	18:10			18:23
16:45			17:00	17:12	17:20	17:31		17:35	17:46	17:54	18:05		18:17		18:35
	16:55		17:09	17:21	17:29	17:40		17:45	17:56	18:04	18:15	18:26		18:46	
		17:08	17:19	17:31	17:39	17:50		17:55	18:06	18:14	18:25		18:37	18:57	
	17:17		17:31	17:43	17:51	18:02		18:07	18:18	18:26	18:37	18:48			18:53
		17:28	17:39	17:51	17:59	18:10		18:20	18:31	18:39	18:50		19:02		19:05
	17:40		17:53	18:03	18:10	18:19								18:29	

This schedule provides an eight-minute headway for about 40 minutes in the peak of the peak period. Note that with an eleventh bus, the cycle calculates to 88 minutes (8 x 11 buses). But our adjusted round trip running time is 89 minutes! The reason that this schedule works is that the eight-minute headway is in place for only about half the peak round trip cycle. Some buses will not be making a full cycle during the time when the headways are tightest and running time longest and therefore will not require the full 89 minutes allocated to a round-trip. It is always smart to draft a revised schedule and not to rely solely on the cycle calculation.

There are some tight layover situations at both ends of the route. Usually, no bus faces tight layover twice, with the exception of the southbound trip leaving Rugby Circle at 15:57. It gets just two minutes at Sand Point and then only two minutes on arrival at Rugby Circle at 17:23. In most other cases, a minimum layover is followed by a more generous layover time at the other end. Some systems' layover rules might not allow this, but on many properties, minimum layover is specifically allowed during peak times.

Note also that the northbound headways are not uniform. The 17:17 trip departing Wishram provides a 12-minute headway further up the line in a period where other buses are running 10 minutes apart. This two-minute delay to the departure was done in order to allow enough layover for the trip arriving Wishram at 17:15 to be able to hook to it.

The trip adjustments also show up in less than ideal leaving times from the outer terminals, particularly Sand Point. Leaving times would be more uniform if the 16:23 Sand Point departure could be moved to the next earlier trip, which would have it leave at 16:15. This earlier trip is a pull-out at 16:11, which fits into the route at Pasco & Essex, just as other pull-outs to that point have been scheduled. To make the earlier trip the Sand Point trip presents logistical problems, specifically what to do with the bus that arrives at Sand Point at 16:15. Sending the bus out with zero layover is not an option. And if the 16:15 departure is scheduled using the pull-out, another Sand Point departure would be needed to have something for the 16:15 arrival to hook up with. The 16:23 departure could be left alone, but this trip would be a waste, scheduled just eight minutes after the previous departure. In addition, the scheduled pull-out at 16:11 would have to leave from the garage at about 15:55, adding another 16 minutes to the platform time of the schedule. A good scheduler always weighs these adjustments to see which one would provide the greatest service at the least cost. In this case, the swapping of trips is considered unnecessary in view of what would be gained, and the northbound schedule is not changed.

Undoubtedly there are other minor ways the northbound trip grid could have been adjusted to achieve a similar result, but the one shown does the job. It provides sufficient running time, a

Tip The addition of peak buses is not a trivial matter at any system. Because of budget constraints, on most systems, the addition of a peak bus on one route might require that the bus be taken from another route, so that the overall system does not have a net increase. In many cases, transit systems experience unbalanced peaks, requiring more buses in one peak than the other. If our sample system has its highest bus count in the AM peak, then adding a PM peak bus is not as difficult, even though there will be a cost consequence for the additional hours. The true scheduling practitioner simply does not part with another bus unless all other alternatives have been exhausted.

reasonably even headway and distribution of trips from the end terminals, and two new southbound trips, all for the two additional buses.

Now that the trips are in place, the next steps are to make sure that every trip hooks properly and then begin the process of reblocking, starting at the beginning of the PM pull-outs. These steps will be addressed in the advanced section of Chapter 4. A sneak preview: there is enough of a change that no block finishes its day the same as it did in the original schedule. The changes will add two peak buses, as we noted here, and about four platform hours. The final schedule is shown below.

SCHEDULE SHEET with adjusted running time and headways

Route 96 IN EFF:
MONDAY THRU FRIDAY
Part 1

	NORTHBOUND								SOUTHBOUND							
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	IN GAR	LVE.
5	4:10								4:20	4:28	4:35	4:43		4:53		5:05
1	3:45	4:05		4:18	4:26	4:33	4:41		4:50	4:58	5:05	5:13		5:23		5:35
6	4:55								5:05	5:13	5:20	5:28	5:37			5:49
3	4:05	4:35		4:48	4:56	5:03	5:11		5:20	5:29	5:37	5:47		5:57		6:05
7	4:39		4:59	5:08	5:16	5:23	5:31		5:35	5:44	5:52	6:02	6:12			6:19
5		5:05		5:19	5:29	5:37	5:46		5:50	5:59	6:07	6:17		6:27		6:45
9	4:59		5:19	5:29	5:39	5:47	5:56		6:05	6:14	6:22	6:32	6:42			6:57
1		5:35		5:49	5:59	6:07	6:16		6:20	6:29	6:37	6:47		6:57		7:05
6			5:49	5:59	6:09	6:17	6:26		6:35	6:44	6:52	7:02	7:12			7:17
3		6:05		6:19	6:29	6:37	6:46		6:50	7:01	7:10	7:21		7:32		7:45
7			6:19	6:29	6:39	6:47	6:56		7:05	7:16	7:25	7:36	7:46			7:57
8	5:55	6:25		6:39	6:50	6:59	7:10		7:15	7:26	7:35	7:46		7:57		8:05
4	6:17		6:37	6:49	7:00	7:09	7:20		7:25	7:36	7:45	7:56	8:06			8:23
5		6:45		6:59	7:10	7:19	7:30		7:35	7:46	7:55	8:06		8:17		8:35
9			6:57	7:09	7:20	7:29	7:40		7:45	7:56	8:05	8:16	8:26		8:46	
1		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37		9:05
6			7:17	7:29	7:40	7:49	8:00		8:05	8:16	8:25	8:36	8:46			8:53
10	6:55	7:25		7:39	7:50	7:59	8:10		8:15	8:26	8:35	8:46		8:57	9:17	
2	7:17		7:37	7:49	8:00	8:09	8:20		8:25	8:36	8:45	8:56	9:06			9:23
3		7:45		7:59	8:10	8:19	8:30		8:35	8:46	8:55	9:06		9:17		9:35
7			7:57	8:09	8:20	8:29	8:40		8:45	8:56	9:05	9:16	9:26		9:46	
8		8:05		8:19	8:30	8:39	8:50		8:55	9:06	9:15	9:26		9:37	9:57	
4			8:23	8:34	8:44	8:52	9:02		9:07	9:18	9:27	9:38	9:48			9:53
5		8:35		8:48	8:58	9:06	9:16		9:22	9:32	9:40	9:50		10:01		10:05
6			8:53	9:04	9:14	9:21	9:31		9:37	9:46	9:53	10:03	10:13			10:23
1		9:05		9:18	9:28	9:35	9:44		9:52	10:01	10:08	10:18		10:29		10:35
2			9:23	9:33	9:43	9:50	9:59		10:07	10:16	10:23	10:33	10:43			10:53
3		9:35		9:48	9:58	10:05	10:14		10:22	10:31	10:38	10:48		10:59		11:05
4			9:53	10:03	10:13	10:20	10:29		10:37	10:46	10:53	11:03	11:13			11:23
5		10:05		10:18	10:28	10:35	10:44		10:52	11:01	11:08	11:18		11:29		11:35
6			10:23	10:33	10:43	10:50	10:59		11:07	11:16	11:23	11:33	11:43			11:53
1		10:35		10:48	10:58	11:05	11:14		11:22	11:31	11:38	11:48		11:59		12:05
2			10:53	11:03	11:13	11:20	11:29		11:37	11:46	11:53	12:03	12:13			12:23
3		11:05		11:18	11:28	11:35	11:44		11:52	12:01	12:08	12:18		12:29		12:35
4			11:23	11:33	11:43	11:50	11:59		12:07	12:16	12:23	12:33	12:43			12:53
5		11:35		11:48	11:58	12:05	12:14		12:22	12:31	12:38	12:48		12:59		13:05
6			11:53	12:03	12:13	12:20	12:29		12:37	12:46	12:53	13:03	13:13			13:23
1		12:05		12:18	12:28	12:35	12:44		12:52	13:01	13:08	13:18		13:29		13:35
2			12:23	12:33	12:43	12:50	12:59		13:07	13:16	13:23	13:33	13:43			13:53
3		12:35		12:48	12:58	13:05	13:14		13:22	13:31	13:38	13:48		13:59		14:05
4			12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:14			14:23
5		13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:30		14:35
6			13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:44			14:53
1		13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		15:00		15:05

SCHEDULE SHEET with adjusted running time and headways

Route 96 IN EFF:
MONDAY THRU FRIDAY

Part 2

	NORTHBOUND								SOUTHBOUND							
BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	IN GAR	LVE.
2			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14			15:23
3		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30		15:35
4			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44			15:48
5		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00		16:05
15	15:23								15:33	15:44	15:52	16:03	16:15			16:23
6			14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28		16:30
1		15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39			16:41
2			15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52		16:55
3		15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05			17:08
12	16:19								16:29	16:41	16:50	17:02		17:15		17:17
4			15:48	15:58	16:09	16:16	16:26		16:37	16:49	16:58	17:10	17:22			17:28
13	15:53			16:08	16:19	16:26	16:36		16:45	16:57	17:06	17:18		17:31		17:40
5		16:05		16:18	16:29	16:36	16:46		16:53	17:05	17:14	17:26	17:38			17:53
14	16:11			16:26	16:38	16:46	16:57		17:01	17:13	17:22	17:34		17:47	18:07	
15			16:23	16:34	16:46	16:54	17:05		17:09	17:21	17:30	17:42	17:54		18:14	
6		16:30		16:44	16:56	17:04	17:15		17:17	17:29	17:38	17:50		18:03		18:05
1			16:41	16:52	17:04	17:12	17:23		17:25	17:37	17:46	17:58	18:10			18:23
11	16:45			17:00	17:12	17:20	17:31		17:35	17:46	17:54	18:05		18:17		18:35
2		16:55		17:09	17:21	17:29	17:40		17:45	17:56	18:04	18:15	18:26		18:46	
3			17:08	17:19	17:31	17:39	17:50		17:55	18:06	18:14	18:25		18:37	18:57	
12		17:17		17:31	17:43	17:51	18:02		18:07	18:18	18:26	18:37	18:48			18:53
4			17:28	17:39	17:51	17:59	18:10		18:20	18:31	18:39	18:50		19:02		19:05
13		17:40		17:53	18:03	18:10	18:19								18:29	
5			17:53	18:03	18:13	18:20	18:29		18:35	18:46	18:54	19:05	19:16			19:23
6		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:16		19:27		19:35
1			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:31	19:41			19:53
11		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:51		20:02		20:06
12			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:11	20:21			20:28
4		19:05		19:18	19:28	19:35	19:44								19:54	
5			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:31		20:42		20:46
6		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:51	21:01			21:08
1			19:53	20:03	20:12	20:19	20:26								20:36	
11		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:11		21:22		21:26
12			20:28	20:38	20:46	20:52	20:59		21:05	21:14	21:21	21:31	21:41			21:48
5		20:46		20:58	21:06	21:12	21:19		21:25	21:34	21:41	21:51		22:02		22:06
6			21:08	21:18	21:26	21:32	21:39		21:45	21:54	22:01	22:11	22:21			22:28
11		21:26		21:38	21:46	21:52	21:59		22:05	22:14	22:21	22:31		22:42		22:46
12			21:48	21:58	22:06	22:12	22:19		22:25	22:34	22:41	22:51	23:01			23:08
5		22:06		22:18	22:26	22:32	22:39		22:45	22:54	23:01	23:11		23:22		23:26
6			22:28	22:38	22:46	22:52	22:59		23:05	23:14	23:21	23:31	23:41			23:48
11		22:46		22:58	23:06	23:12	23:19		23:25	23:34	23:41	23:51		0:02		0:06
12			23:08	23:18	23:26	23:32	23:39								23:49	
5		23:26		23:38	23:46	23:52	23:59		0:05	0:14	0:21	0:31		0:42	1:02	
6			23:48	23:58	0:06	0:12	0:19								0:29	
11		0:06		0:18	0:26	0:32	0:39								0:49	

To summarize this section: we took the information from the traffic checks and made a real world example schedule change that incorporated both increased running time and the need for an additional trip. We did it in the least intrusive way, disturbing the riding habits of the patrons of this route to the least extent possible. Our “good scheduler” mentality is partially satisfied with this while the other part wants to go back and see if this adjustment can be done with the addition of only one bus. But remember that preliminary analysis showed the round trip cycle would have been impossibly tight—even more so than in the final schedule.

LEVEL 3A

End of Advanced Schedule Building, Part A

Advanced Schedule Building, Part B continues on the next page.

To jump to Schedule Blocking, go to page 4-1.

3.5 Advanced Topics In Schedule Writing

LEVEL 3B

Establishing Running Times

Setting running times is a topic that generates much discussion and at times controversy within the transit industry. A quick review of available literature will indicate numerous research papers have been written addressing this topic. In addition a number of transit systems have undertaken studies of their own as to how best approach running times methodology.

The survey of transit operators, conducted as part of this project, revealed that taking averages of running time observations continues to be the most common way of setting running times on a route or route segment. Almost 80% of respondents use running time averages, often leavened with professional judgment. In systems without APCs or AVL, the scheduler will typically eliminate any unusual values from the running time observations at hand and average the remaining data. Use of APC and AVL yield many more observations to be included in averages. Does greater availability of running time data allow for new ways to establish running times in a schedule?

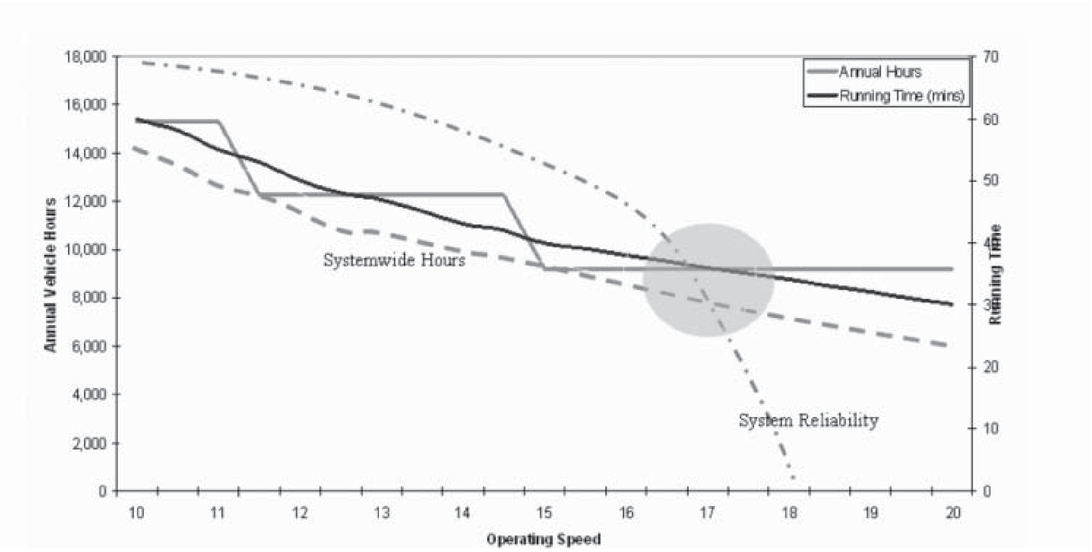
It might provide some perspective for this discussion to consider the scheduler’s goals in setting running times on a route:

1. To provide an accurate and reliable timetable for customers to use. The scheduler wants to set times at each time point with a high probability that the actual arrival or departure time will match the scheduled time. Reliability is an important element of service quality as perceived by the customer.
2. To provide a realistic schedule for operators so that they can drive at a reasonable, safe speed.
3. To ensure an efficient operation. The scheduler has a direct impact on operational costs and, by minimizing unproductive time, can enhance efficiency.
4. To avoid instances of running hot, a major transgression in transit operations.
5. To eliminate or sharply reduce situations where running time is too tight and service runs late or is subject to buses bunching.
6. To maximize on-time performance. As discussed in the intermediate section of this chapter, each agency has a specific definition of “on time.” Typically, a trip is considered on time if it arrives or departs from a time point within 0 to 5 minutes after the scheduled arrival/departure time. Customer information systems may estimate scheduled time at intermediate stops, increasing pressure not to run early prior to a time point.

The impact of running times can be a significant factor in unreliable operations, particularly with regard to bunching of vehicles. While bunching is often caused by varying operating conditions (traffic, congestion, loading variability, etc.) the scheduled run times can affect whether vehicles operate early or late. And once vehicles fall outside the schedule, this affects loadings and can cause bunching.

A critical aspect of running time analysis is that the scheduler is often being asked to simultaneously resolve the opposing requirements of minimizing resources and maximizing on time performance. Providing maximum planned scheduling efficiencies, combined with minimizing passenger travel times, can be in direct conflict with providing achievable times for operators. It is also important to note that possibly the major determinant of transit system efficiency is operating speed.

The graph below provides a basic representation of the overall running time problem from a scheduling perspective. It shows a simple example for one route, indicating the steps as vehicle savings thresholds are achieved. This is an important element of the equation: savings are not linear, but are primarily a step function with costs increasing or decreasing in steps as vehicle requirements increase or decrease. What the scheduler should be moving towards when developing running times is the point where efficiencies are maximized and operating speeds high, but not to the point that degrades system reliability—represented by an area within the shaded area on the graph. This is, in theory, the point at which running times are "optimized," and this point exists for each running time problem.



How does a scheduler go about achieving these goals, and where are the potential pitfalls? Let's look at the first four goals in detail:

1. **Accurate.** As noted earlier in this chapter, the scheduler is trying to schedule for the "average" day that does not really exist. With the wealth of running time data provided by an AVL or APC system, however, he or she can come a little closer. A significant problem is unexpected delays, caused by accidents, temporary street closings, wheelchair boardings, and bicycle mountings and dismountings. One advantage of extensive running time data is that wheelchairs and bicycles are already accounted for in the data, even in cases of non-random occurrences (such as a route serving housing for people with disabilities or a college campus).

   If the standard deviation of the running time is small, then the use of average running time is logical. The more difficult situation is when there is considerable variation in running times. Under those circumstances, the use of an average results in lots of early trips and lots of late trips.
2. **Realistic.** This term can be more difficult to define than is apparent at first glance. An operator obviously wants a schedule that allows him/her to drive safely and arrive at time points on time. Operators also like the ability to take all of their scheduled layover time at the end of a route. However, operators differ in their driving abilities and their ability to keep to schedule. Some observers have noted that "control of the door" is an important factor in an operator's ability to keep to schedule, and variations in driver skill are also undeniable. It is not uncommon to see four runs on a route on time at all time points and a fifth chronically late.

   Provision of sufficient layover time is the most obvious means to control for differences among operators. The interaction between running times and layover will be discussed in more detail below. The scheduler's ability to spot trends like this is important in the process of setting realistic running times. Some agencies also schedule mid-trip "holds" at transfer centers or major stops to help a route stay on schedule. This approach is often used for longer routes.

   Operators will adjust if they view a schedule as unrealistic. They may leave one terminal early, sacrificing layover time at this location to ensure a bigger chunk of layover time at the other terminal. If there is too much time in the schedule (in the late evening, for example), an operator may leave the terminal late knowing that s/he will "catch up" with the schedule later in the route.
3. **Efficient.** As noted earlier, transit cost has a step progression—changes to running time have no impact on cost until an extra bus is required or can be removed, at which point the cost impact is large. The scheduler knows this as well as or better than anyone in the agency, and can make informed decisions regarding changes in running time and

layover time based on this knowledge.

4. **Running hot.** One approach frequently used to avoid running hot is to schedule very tightly on the early segments of a route and provide more generous running time on later segments. This makes it almost impossible to run hot if an operator leaves on time, and yet gives the operator confidence that s/he will be able to take all of the scheduled layover at the end of the trip. Another approach is to schedule very tightly on route segments and provide a more generous layover time.

   A major problem with this approach is accuracy for the customer. At stops along the early segments, the transit vehicle will almost always be a few minutes late. While this is certainly preferable to leaving early, it can create an impression of unreliability among riders, expressed in terms of "the bus is always late." It can also leave the impression with the operator that the schedulers did not do an accurate job of establishing running time and the schedule cannot be reliably followed.

   At some time points, such as the end of the line, arriving early may be considered good for customer service. Why should the driver slow down when traffic is light in a location where no passenger boardings are expected? Some agencies consider an early arrival at a route terminal to be on time.

Agency policies may also affect running time. Policies mentioned in the survey included the requirements that all passengers be seated or that all strollers be folded before the operator leaves a stop. By increasing the dwell time at stops, these policies lengthen running time on all routes. Such policies may be implemented without a full consideration of potential costs.

A brief math review may be appropriate before addressing running time strategies. This chapter has referred several times to "average" running times. Other useful concepts are "median" and "mode." The median is the middle value in an ordered list of numbers. The mode is the most commonly occurring value in a group of numbers.

As an example, consider the two sets of observations of running times on a given route segment shown below. The scheduled running time for this segment is 10 minutes. The first set is very symmetrical, and the average, median, and mode are all identical. If we were to plot this set, it would look like a standard bell curve. The second set is asymmetrical, with one very low running time and several very high running times.

Median and mode are not affected by extreme values, whereas the average is skewed (this is the reason why schedulers would eliminate outliers or extreme values before taking the average). Also, there may be more than one mode in a given data set. While the average is the most familiar and widely used measure, the median value is a good choice for asymmetrical data sets.

We have noted earlier in this manual the types of data that a scheduler uses. The variability of data, in both quantity and quality, is never more evident than when undertaking running times analysis. The best type of running time data is that which provides elapsed running time, both for end-to-end and trip segments. Using this type of data the scheduler can analyze and develop running times based on actual running time observations. It is of significant value if the data identifies long waiting periods along the route. This can identify either key bottlenecks, or locations where operators are waiting due to excessive running time.

NEVER use schedule deviation data by itself as a means for identifying running time issues. Consider a smart operator who knows the route and running times. Knowing excessive running time exists, he/she leaves the trip terminal late to avoid running hot. This late trend continues along the route, until finally arriving on time. The outcome is a series of "late" running observations that could suggest to the uninitiated a need for more running time, when the opposite is true. The reverse can hold true where operators leave early because they know that the scheduled running time is insufficient. Running time analysis requires elapsed running times to ensure meaningful outcomes!

	Running Time Observation 1	Running Time Observation 2
	8	6
	9	9
	9	9
	10	10
	10	10
	10	10
	10	15
	11	15
	11	15
	12	15
Average	10	11.4
Median	10	10
Mode	10	15

Running Time Strategies

What is a scheduler to do? Here are strategies to set running times that have been adopted or proposed at various agencies. Some of these strategies have only become feasible with the advent of APC and AVL systems that provide large volumes of data.

First, we should clarify that establishing different running times at different times of the day and on different days of the week (weekday/Saturday/Sunday) is a standard practice at all but the smallest transit agencies in the survey. This is assumed as an ongoing practice and is not listed as a separate strategy, but one of the implications of differing running times is addressed below.

Use of running time averages, leavened with professional judgment. This continues to be the most common approach among survey respondents to establishing running times. This is a good approach for routes with little variation (i.e., a small standard deviation) in running times. However in most cases the variation observed in running times is significant.

Differentiation by route segment. As discussed above, the strategies of setting minimal running times along early segments of a route and either more generous running times in later segments or more generous layover time are used by many agencies to provide adequate running time while minimizing early departures at time points. If either of these approaches is used, the amount of time taken from initial route segments should be small, leaving a "tight" running time rather than an impossible one. Where a route has high seat turnover, key midpoint destinations, or midpoint connections, this approach can be less valuable.

Use of speed (in miles per hour) to set or evaluate running times. The survey indicated that several agencies use expected or observed speeds to set running times. Some use posted speed limits and then factor the resulting running times to account for stops.

Many schedulers check the reasonableness of scheduled running times for route segments by calculating the scheduled speed for each segment (segment distance divided by scheduled running time). Below is an example of a running time matrix with average speeds included. The scheduler made running time changes on Segments BC, CD, FG, and GH (highlighted), and is using calculated speeds to assess whether the proposed running times are realistic. Point C is the downtown terminal, so the lower scheduled speeds are logical. Point G is a regional mall, so lower speeds during hours of major activity at the mall (in the base and PM peak) are also reasonable.

		AM Peak		Base		PM Peak		Night	
Distance	Segment	Time	Speed	Time	Speed	Time	Speed	Time	Speed
2.83	AB	11	15.4	12	14.2	12	14.2	11	15.4
2.01	BC	11	11.0	11	11.0	11	11.0	8	15.1
0.99	CD	5	11.9	6	9.9	6	9.9	5	11.9
1.52	DE	8	11.4	9	10.1	9	10.1	7	13.0
2.15	EF	8	16.1	9	14.3	9	14.3	7	18.4
2.57	FG	11	14.0	13	11.9	13	11.9	9	17.1
3.80	GH	15	15.2	17	13.4	18	12.7	14	16.3
4.87	HI	20	14.6	19	15.4	20	14.6	16	18.3
1.81	IJ	7	15.5	6	18.1	6	18.1	6	18.1
22.55	Total	105	13.5	111	12.8	113	12.5	93	15.6

Use of percentiles in establishing running times. This strategy becomes possible with large amounts of running time data. One survey respondent reported setting running times on a route so that:

- 65% of all trips finish in time for the operator to take the minimum layover. As an example, if the scheduled running time of a trip is 51 minutes with nine minutes of scheduled layover and a contract stipulation of 10% minimum layover, then 65% of trips are completed no more than three minutes late (to allow for the minimum six minutes layover time);
- 90% of all trips finish in time for the operator to start the next trip on time. In this example, 90% of all trips are completed no more than nine minutes late;
- 10% of all trips finish too late to start the next trip on time.

Percentiles may not be familiar to all schedulers, so a brief refresher is useful. The value of the 90th percentile is a number that is equal to or greater than 90% of all observations in the data set. Similarly, the 40th percentile is a number (lower than the 90th percentile) that is equal to or greater than 40% of all observations. The 50th percentile is the median.

TCRP Report 113 discusses how AVL-APC data can be used to set running times at the route and segment level.[2] Route-level approaches include percentile-based strategies such as:

- Setting running time at the 85th percentile of observed running times (in other words, running times are set so that 85% of all trips finish on time).
- Setting the one-way running time plus layover at the end of the one-way trip at the 95th percentile of observed running times and setting layover time at the difference between the the 95th and the 85th percentile of observed running time (meaning that 85% of all trips finish on time and 95% can start the next trip on time).

TCRP Report 113 notes that these strategies must be coupled with an operating practice of holding at time points, reflecting a trade-off between on-time performance and travel speed. This trade-off is evaluated differently at different agencies. The use of a high percentile means that running time will be relatively high. Many schedulers see high running times and holding at time points as fatal operational flaws in the approach, arguing that you should never write a schedule that deliberately puts an operator in a position where he/she needs to hold at a time point.

Many schedulers would favor use of a much lower percentile. TriMet is quoted in *TCRP Report 113* as suggesting a low percentile criterion because running early is more harmful to passengers than running late. As an example, segment-level running times can be set at the 40th percentile of observed cumulative (from the start of the line to a given time point) running time to guard against running hot. Another survey respondent in this study reported using the 60th percentile as a reasonable guide in setting running times.

"Cumulative" is an important concept in establishing running times. Previous sections of this chapter emphasized setting running times at the route level and then distributing it appropriately across route segments. Taking the opposite approach of establishing running times for each segment and then aggregating for the entire route runs the risk of rounding errors and inaccurate overall route running time, especially as half-minute increments have fallen into disuse.

This is a different way, enabled by much greater availability of data, of thinking about running time. Scatter diagrams showing the distribution of running times for a given direction and segment (or for the route as a whole) allow the scheduler to see where the percentile lines fall and how these relate to the outliers. AVL/APC outputs can provide the raw data to construct scatter diagrams, and some computerized scheduling packages include modules that automatically create these diagrams.

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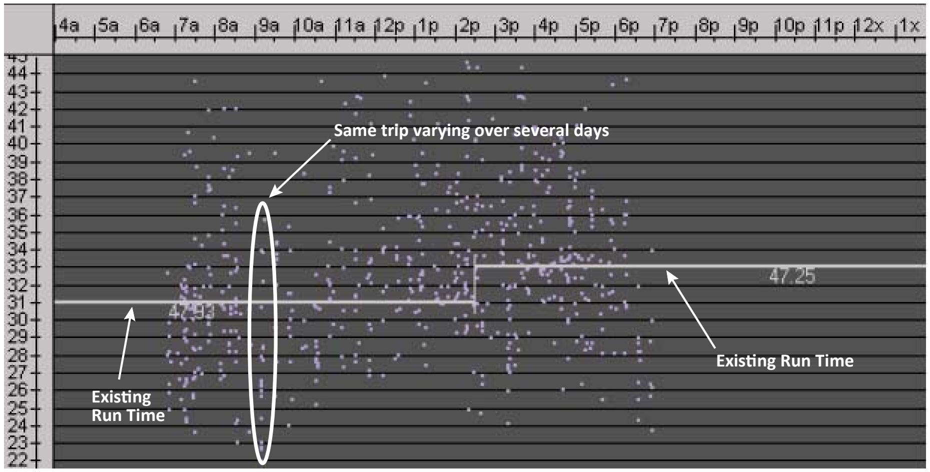
[2] Furth, P.G., B. Hemily, T.H.J. Muller, and J.G. Strathman. TCRP Report 113: Using Archived AVL-APC Data to Improve Transit Performance and Management. Transportation Research Board of the National Academies, Washington, D.C., 2006. See especially chapters 4 and 5.

A real-world example of a scatter diagram is shown below, based on real observations from an AVL system (reproduced from the Hastus ATP system). Each dot represents an end-to-end running time observation, at a certain time of day. There are many days of data in this example and so the same trip may appear many times (as many dots), with the same or different observed running times. The variation in running times is notable but not unusual. Scheduled running time is shown as a horizontal bar.



This example is explored at greater length in the ***Advanced Practices—Running Time and Layover*** discussion later in this section.

The discussion highlights a lack of consensus at this point as to where to "draw the line" in using the percentile approach. Many schedulers favor use of a lower percentile, both to avoid running hot and to avoid unnecessary passenger delays as buses sit waiting for time throughout the system. The more important point here is to develop the ability to make practical use of the reams of data produced by APC/AVL systems. After a few sign-ups, the effect on schedule adherence of setting running times using X percentile will be apparent, at which point the scheduler may conclude that this approach works or may experiment with use of a different percentile.

The percentile approach is just one of many statistical means of developing running times. The use of percentiles is arguably simplistic in that it fails to grasp the variability of running times sufficiently, nor does it allow for consideration of different types of frequency distribution. Some agencies utilize tools that try to estimate a "least cost function," where a large data set is included as input, and then various running time options are applied. The set of running times that results in the lowest "cost" (determined based on applying costs to late or early running) is provided as the "optimal" output.

The availability of larger volumes of data does not necessarily call for changes in traditional means of establishing running times. It does, however, allow more sophisticated models of running times analysis and development to be undertaken. One scheduler suggested that schedules based on (1) the average running time from APC/AVL data less approximately two minutes for the first segment and (2) the average running times for all subsequent segments can increase on-time performance.

Headway-based schedules. This strategy was employed in the implementation of Bus Rapid Transit (BRT) service in Los Angeles. Because a goal of BRT was to provide faster trips, no intermediate time points were initially established: the BRT bus would never be held at a time point. The buses would leave from the terminal every X minutes, and on-street supervision would assist in maintaining this spacing throughout the route. In scheduling terms, BRT buses were given **free running time**. While additional street supervision was an effective tactic in achieving consistent headways, intermediate time points were eventually introduced to aid in controlling the route and avoiding bus bunching. An AVL system could make a headway-based schedule functional, with extensive monitoring of current conditions along the route. The key here is the presence of effective street supervision at all points where buses may become bunched or be inordinately delayed.

As AVL and APC systems become more established and the volume of available data increases exponentially from today, schedulers will experiment with various approaches to establishing running time. Multiple techniques may even be used at a single agency, depending on the variability in running time on a specific route. Continued experimentation with innovative approaches will benefit the industry as a whole.

free running time

The absence of a specified running time along a given segment, with an estimated arrival time at the end of the segment. Frequently used on the express portion of an express bus trip, free running time is a component of headway-based schedules and is sometimes included on the last segment of a local route.

intertiming

The process of scheduling trips of two or more routes that share a common segment in a manner that evenly spaces the trips over the common segment. Intertiming is intended to provide more frequent service for those passengers who begin and end their trips within the shared segment.

Intertiming with Even and Uneven Headways

In most transit systems, there is a corridor segment served by two (or more) otherwise unrelated routes. Coordination of schedules along this segment can maximize the frequency of service. This process of schedule coordination is known as intertiming.

Intertiming is easiest when both routes have the same headway. For example, if Route X and Route Y both have 10-minute headways, their schedules can be intertimed as follows:

Route X	Route Y
:00	:05
:10	:15
:20	:25

The intertiming of the two routes provides a five-minute headway along the route segment. When headways differ, the scheduler must figure out a coordination scheme where both headways will fit together without causing two trips to occur at the same time. Depending on the incompatibility of the two headways, one or more of the trips each hour (or however often the pattern repeats) may have to be moved to form an uneven headway on one of the routes. The scheme is developed first for off-peak times. Service during peaks may be frequent enough so that coordination is neither feasible nor really necessary.

For one example of combining and blending headways, consider the following: Route X operates every 15 minutes, at :05, :20, :35 and :50 past the hour. Route Y operates every 20 minutes, at :10, :30 and :50 past the hour. The obvious conflict here is the two trips operating at :50, plus other trips operating within five minutes of each other. The simplest course of action is to move one of the :50 trips, but all this will accomplish is to give an uneven headway to one of the routes. To optimize the situation, both routes need to be intertimed. The combined routes offer seven trips per hour over the common segment, which works out to four trips on a 9-minute headway and three trips on an eight minute frequency—an average 8.6-minute headway. But an even headway will not work, since there is a missing Y trip each hour which will leave a gap between a pair of X trips. One possible blending scheme is shown below.

Route X	Route Y
	:04
:10	
	:20
:29	
	:37
:47	
	:53

The blended headways vary from six to ten minutes, bunching around the missing Y trip. Though not perfect, the scheme does a credible job of spacing trips on the shared corridor segment as well as on the individual route segments. Of greater importance, it eliminates the wasteful practice of scheduling two trips together.

Intertiming is most useful when the common segment is relatively long, there is extensive boarding and alighting activity, and many trip origins and destinations are along the common segment. If these conditions do not hold, then intertiming may not be necessary.

A variation of blended headways is the merging of local and express service on the same route. In some cases the headways of the two services are the same, but the running time is different. The concern in this situation is where on the line the vehicles should be evenly spaced versus where the express will pass the local. Depending on the length and other characteristics of the line, the scheduler may have only one point where the trips can be evenly spaced. That point will most likely be the max point. The point where the express vehicle passes the local vehicle is of less importance on bus routes. For rail or trolley coach routes without facilities for passing, the scheduler will have to be innovative, starting the express trip just ahead of the local and applying running time (and possibly a headway adjustment) so the express does not catch up to the next local before the end of the route or the appropriate turnback location.

Sometimes the scheduler deliberately wants the headway to be an uneven interval. The most common situation is when every other trip on a route turns short of the normal route end. Giving the short-turn trips a wider headway can even out ridership levels between through and short-turn vehicles. For example, if a route has a seven- to eight-minute headway, the trips could be arranged to operate six and nine, with the nine-minute interval given to the short-turn trip, as shown below:

Through Trip	Short-turn
	:00
:09	
	:15
:24	
	:30
:39	
	:45
:54	

Assuming random passenger arrivals, more passengers will be waiting for the short-turn vehicle, since they have nine minutes to gather at any given stop as opposed to six minutes for the through vehicle. This means that more passengers who can take either service will be on the short-turn vehicle, which should even out the loads between the two

Two considerations apply to using uneven headways. First, the effect of moving a trip by a minute or two diminishes as the headway widens. Any headway over 10 minutes probably would not benefit from the adjustment. Second, fine tuning touches by the scheduler will be most effective with good street supervision to keep the trips from bunching.

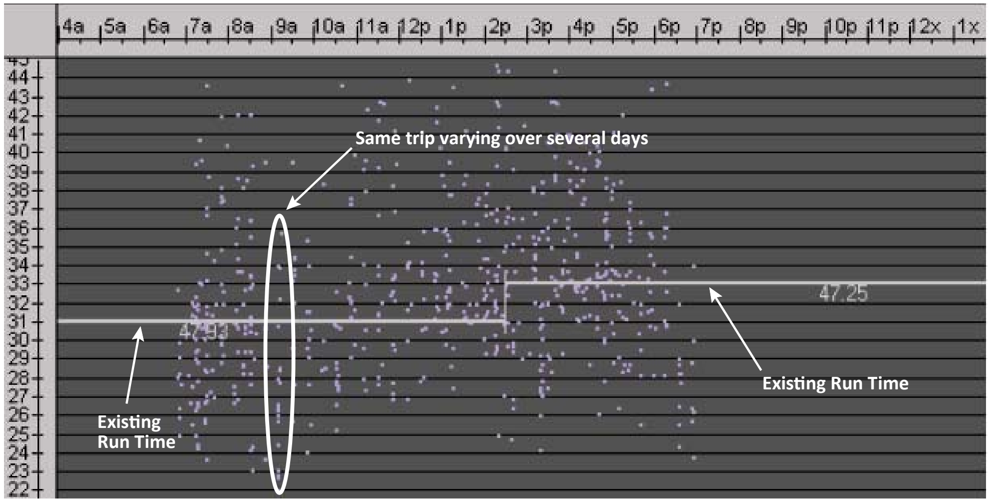
Finally, there is the issue of standardization of running times along the common segment. This issue may be addressed in the labor agreement, and it is a logical idea, but in certain circumstances it may be the wrong idea. Reasons to avoid strict standardization include: different dwell times on routes with different destinations and ridership, and performance of different bus types. Where standardization is enforced by computerized scheduling software, schedulers work around it when necessary by defining different pairs of time points for different routes.

Advanced Practices—Running Times and Layover

Previous running time discussions focused primarily on how best to set running times for a given set of available data. The discussions alluded to but did not directly address the important interaction between running times and layover time. In "optimizing" running times it is wise to consider layover requirements and implications, in order to prepare the "best" schedule.

In many cases, running time variations limit the scheduler's capacity to set an "optimal" run time that results in high levels of on time running. Consider the following running time diagram, shown earlier and based on real observations from an AVL system (reproduced from the

Hastus ATP system). Each dot represents an end-to-end running time observation, at a certain time of day. There are many days of data in this example and so the same trip may appear many times (as many dots), with the same or different observed running times. The existing running time is shown as a line that changes across the day as the running time periods change.



In this example, there is little chance for the scheduler to develop any proposed running times that will result in a high level of on-time performance. The observations are simply too variable. In our experience this is not unusual, even for smaller systems without significant congestion issues.

There may or may not be an operational solution to the running time variability. The scheduler should bring this variability to the attention of operations staff, to see if resolution is possible. This brings us to an important point: **not all running time problems are scheduling issues!** Many transit systems fail to see this point and attempt to solve an operational or variability problem by changing scheduled running times. The outcome tends to be poor reliability and inefficient operations.

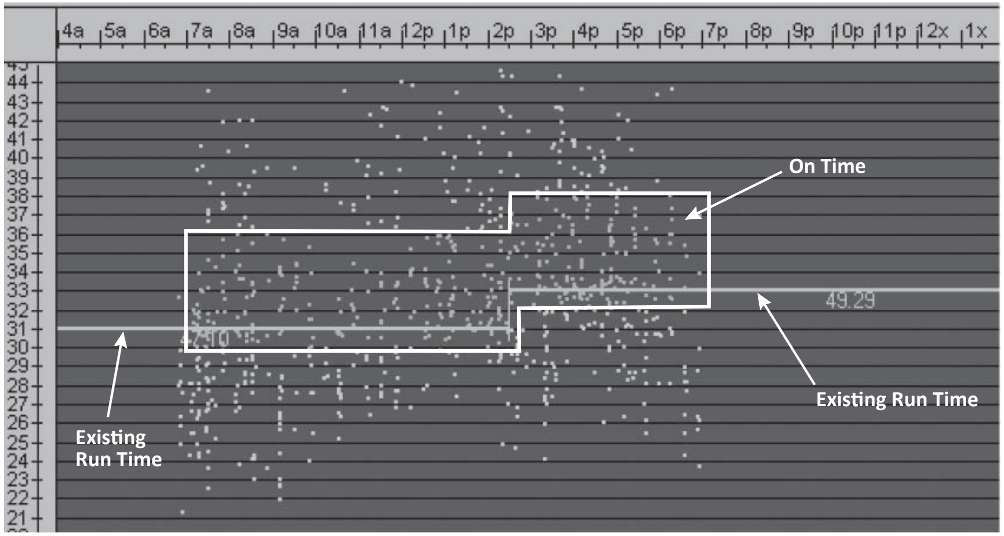
In the above example the only way any reasonable form of reliability can be built into the schedule is through provision of sufficient layover to allow “next trips” to depart on time. This is where joint consideration of running time and layover time comes into consideration. Inclusion of both running times and layover times in the optimization process is a necessary approach to maintaining operational reliability.

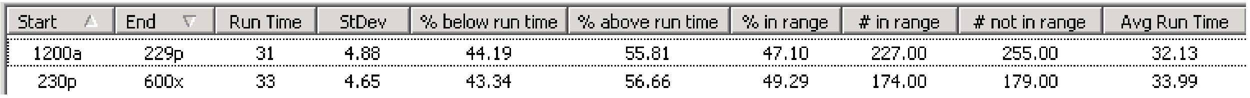
In the above example the running time can arguably be set anywhere within a range from 30 to 37 minutes. For any running time within this range, there will be high levels of late and/or early running and probably only 40-50% "on time" (however it is defined). However, if we simultaneously consider running time and layover time, we can at least ensure that the next trip can depart reliably and hopefully avoid the all-day cascading impact of late departures on on-time performance.

An example using charts & data tables from the Hastus ATP system with a combination of graphical data views, statistical approaches, and scheduler experience can demonstrate how to develop a solution.

The chart below shows the same data set of observed running times. The on-time range of one minute early to five minutes late is indicated on the chart. The horizontal line represents existing running time, which changes across the day as the running time periods change. The percentage of trips within the "on time" category shows below the running time.

A table of information about the observations is also provided. The "percent below run time" is the same as the percentile discussed in a previous section; in this case, running time is scheduled at the 43rd or 44th percentile. Note this is a large data set that covers multiple operating days. For this kind of analysis, the availability of AVL/APC systems allows this kind of rich data set to be used for more effective running time analysis.

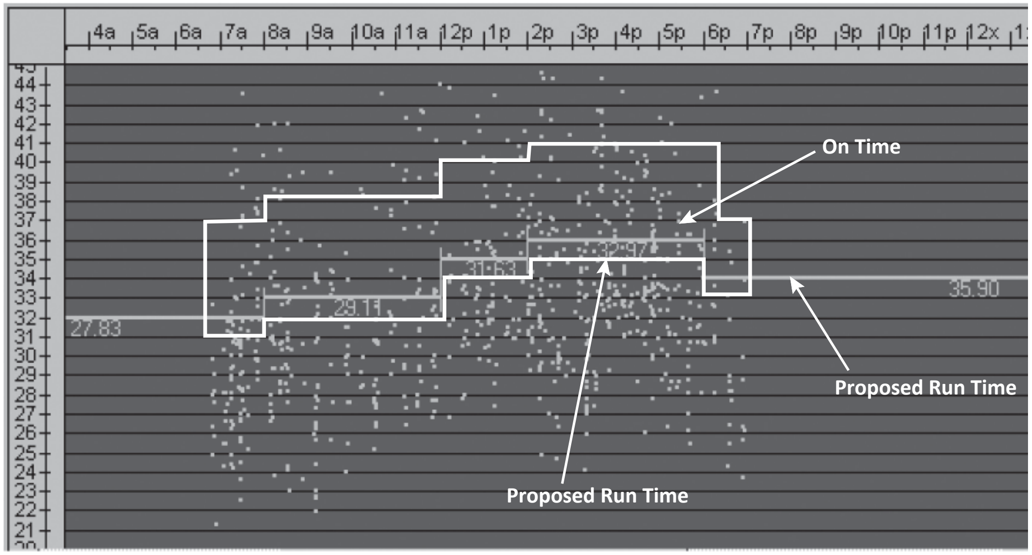


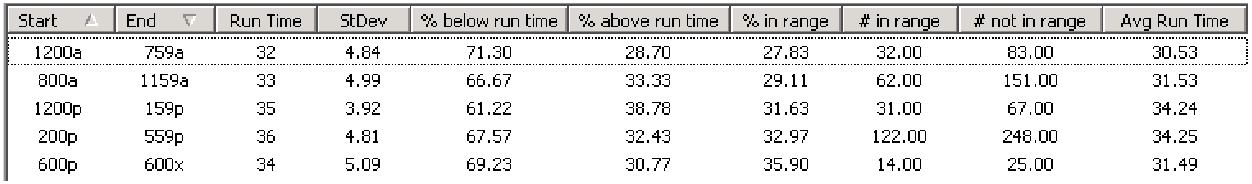


Start	End	Run Time	StDev	% below run time	% above run time	% in range	# in range	# not in range	Avg Run Time
1200a	229p	31	4.88	44.19	55.81	47.10	227.00	255.00	32.13
230p	600x	33	4.65	43.34	56.66	49.29	174.00	179.00	33.99

The scheduler is faced with a difficult assignment. Clearly there is major running time variability, and setting any run time at any level will not necessarily satisfy the aims described previously. However, since we are charged with the responsibility of developing run times, we push on, and try to generate a proposed set of times.

An automated method of "optimizing" on-time running, based on a basic mathematical model, is applied. The figure & table below indicate the outcome.





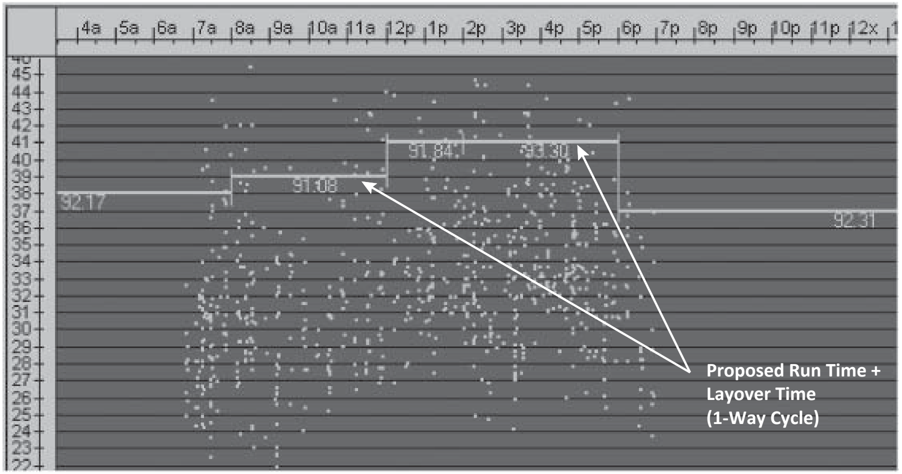
Start	End	Run Time	StDev	% below run time	% above run time	% in range	# in range	# not in range	Avg Run Time
1200a	759a	32	4.84	71.30	28.70	27.83	32.00	83.00	30.53
800a	1159a	33	4.99	66.67	33.33	29.11	62.00	151.00	31.53
1200p	159p	35	3.92	61.22	38.78	31.63	31.00	67.00	34.24
200p	559p	36	4.81	67.57	32.43	32.97	122.00	248.00	34.25
600p	600x	34	5.09	69.23	30.77	35.90	14.00	25.00	31.49

The scheduler (using the mathematical approach and then some manual manipulation) has done a reasonable job here of providing adequate running time without excessively slowing the service down. Note, however, that a large number of trips can potentially run early (those observations below the line). In fact between 60% and 70% of observations fall below the proposed time (another way of saying that running time is scheduled at the 60th or 70th percentile). In addition, there are still many trips that will not have enough running time (those observations above the line). The number of trips with "on time" running time, according to the table, is only around 30% to 35%.

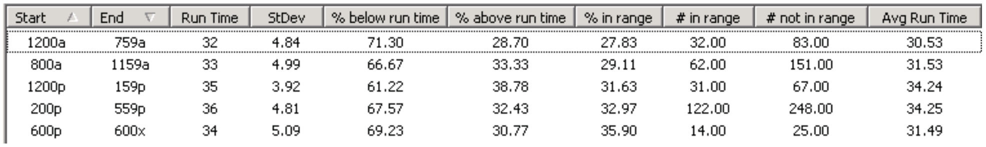
This is a reasonable solution, but is probably not optimal. What if we consider running time and layover time together? The goal is to set both at a level that allows a high percentage of on-time next trip departures. Transit agency policy may guide this decision or it may be totally up to the scheduler, based upon the individual transit system.

The figure & table below show recovery plus layover times set at around the 93rd percentile. That is, if running time plus layover between 2 PM and 6 PM is set at 41 minutes, 93% of next trips will depart on time. The dots above the line are those that would depart the next trip late.

Given the proposed running time of 36 minutes, (see above), the layover time proposed would be five minutes during this period. Using this approach, over 93% of next trips will depart on time based upon the data set.



Proposed Run Time + Layover Time (1-Way Cycle)



Start	End	Run Time	StDev	% below run time	% above run time	% in range	# in range	# not in range	Avg Run Time
1200a	759a	32	4.84	71.30	28.70	27.83	32.00	83.00	30.53
800a	1159a	33	4.99	66.67	33.33	29.11	62.00	151.00	31.53
1200p	159p	35	3.92	61.22	38.78	31.63	31.00	67.00	34.24
200p	559p	36	4.81	67.57	32.43	32.97	122.00	248.00	34.25
600p	600x	34	5.09	69.23	30.77	35.90	14.00	25.00	31.49

This is an appropriate point for the scheduler to consider if 93% is sufficient. It may be that a higher level is needed to ensure service reliability at policy levels for your system. In the example above, adding four additional minutes to the layover time, for a total of 45 minutes running time plus layover, would provide sufficient time for all trips within the afternoon time period to depart the next trip on schedule.

During this process, the trade-off between cost and reliability comes into play, and the skill and experience of the scheduler is required. By adding those extra four minutes (so a minimum layover of 10 minutes) it may cost an additional vehicle. This then becomes a policy decision—would the transit system be prepared to incur the additional cost to achieve the additional service reliability? In real terms, the tradeoff comes down to ensuring a couple of additional trips departing on time versus the annual cost of an additional vehicle. There is of course no one answer to that question—it will vary by transit system—but it is fair to say that most agencies would accept a 93% next-trip departure rate under these circumstances.

When considering running time and layover time simultaneously, we are essentially determining minimum layover. The scheduling limitations and round-trip cycles may result in higher-than-minimum-specified layovers. In this example, at a 41 minute run time plus layover may actually end up as 45 minutes if the running time is the same in both directions, and the frequency is 30 minutes.

Layover requirements are discussed elsewhere in this manual. During that discussion, the concept of layover being a function of running time variability was noted. In an example like this one, layover is used as a means of dealing with run time variability, regardless of the level of running time being set, because for running time data with high variability, the scheduled running times cannot achieve the necessary reliability levels.

In this example the running time could set at a much lower level, let's say around the average of 33 minutes. In that case, running time plus layover time would still be 41 minutes, and the minimum layover would be eight minutes.

In many transit systems the graph above is representative of actual operations and running time variability is high. In this situation the joint consideration of running time and layover time is as important to the system reliability as the development of running times.

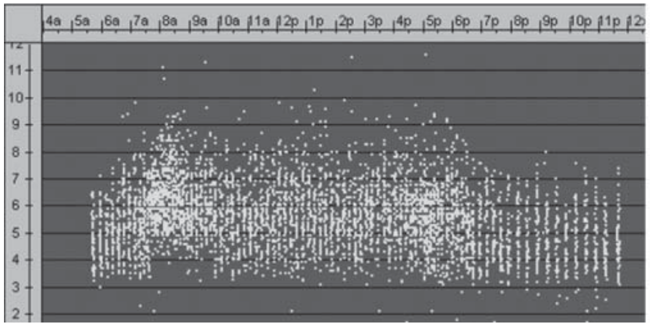
How Many Running Time Periods?

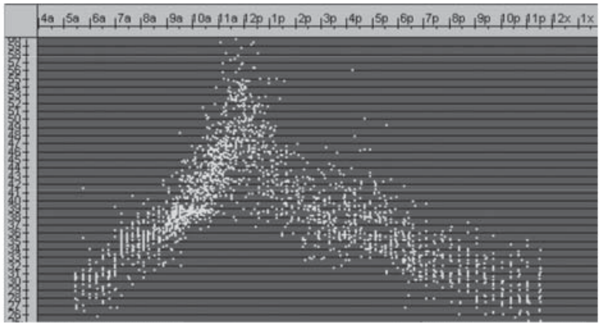
The number of running time periods can determine how reliable a schedule is. In theory, more periods result in better on-time performance.

However, this comes at a cost to the simplicity of the schedule. In the extreme, a single all-day running time period allows a simple all-day headway to be developed. Conversely, changing running times results in more complex schedules, where the clock face can only be maintained during specific time periods. Where running times change dramatically and often, the headway is compromised, since successive trips have different running times and the headway is different at various time points along the route.

There is no "right" answer. The scheduler needs to be guided by the data and the analysis. In many cases, the analysis tool can recommend running times periods. As with many "tools," the scheduler must realize that the mathematical answer is not necessarily the best operational answer, and fewer running time periods may be warranted.

Take the two examples below. The shape of the data indicates immediately that only a few running time periods are needed for the example on the left, whereas a range of time periods are needed for the example on the right, to reflect the changing running time trends.





In cases where running time variability is high enough that a range of running times can be applied with similar outcomes to the same data set, adding additional running time periods is not worth the complexity, as estimating run times to such a level of precision is optimistic. The recommendation is not to overuse running time periods. Having noted this, however, it is likely that for most transit routes operations will be faster late at night, early in the morning, and during some weekend periods. These trends should be reflected in the running times.

As with all aspects of scheduling the scheduler should be guided by experience, common sense, and good operations principles when deciding on how many running time periods are required for a route.

Transitioning of Running Time Periods

A second aspect of the number of running time periods relates to how running period transitions are handled. The intermediate section of this chapter discussed transitions, but the topic deserves further attention here.

Let's start with a simple example—one route with several running time transitions during the AM Peak. The run times are set out below.

	5:00 to 5:59	6:00 to 6:59	7:00 to 8:29	8:30 to 9:29	9:30 to 14:59
A	-	-	-	-	-
B	5	7	8	7	6
C	8	9	10	9	9
D	7	8	10	8	7
E	6	7	9	7	7
Total	26	31	37	31	29

Note that the peak period time rises quite steeply. This example illustrates the problems that such running time changes may pose. A schedule is provided below, based upon the proposed running time periods.

A	B	C	D	E	Run Time
5:55	6:00	6:08	6:15	6:21	26
6:15	6:22	6:31	6:39	6:46	31
6:30	6:37	6:46	6:54	7:01	31
6:45	6:52	7:01	7:09	7:16	31
7:00	7:08	7:18	7:28	7:37	37
7:15	7:23	7:33	7:43	7:52	37
7:30	7:38	7:48	7:58	8:07	37
7:45	7:53	8:03	8:13	8:22	37
8:00	8:08	8:18	8:28	8:37	37
8:15	8:23	8:33	8:43	8:52	37

A	B	C	D	E	Run Time
8:30	8:37	8:46	8:54	9:01	31
8:50	8:57	9:06	9:14	9:21	31
9:10	9:17	9:26	9:34	9:41	31
9:40	9:46	9:55	10:02	10:09	29
10:10	10:16	10:25	10:32	10:39	29

Note that the relatively large running time changes results in a compromised headway. For example, the run time increase at 7 AM results in a 19-minute headway at Point D, yet the prescribed headway is 15 minutes. Conversely, as running times are reduced at the end of the peak a short nine-minute headway occurs at Point E. Such schedules can result in unstable operation and probably do not reflect “real-life” operating conditions. It is unlikely that the running time increases by six minutes between 6:59 AM and 7:00 AM. Instead this increase is likely to be a transition over a few trips, as traffic and patronage increase.

The scheduler should fine-tune the schedule accordingly. An updated example, with transitioned times, is provided below. The trips that have been “smoothed,” with non-standard running times, are highlighted.

A	B	C	D	E	Run Time
5:55	6:00	6:08	6:15	6:21	26
6:15	6:21	6:29	6:37	6:44	29
6:30	6:37	6:46	6:54	7:01	31
6:45	6:52	7:01	7:10	7:18	33
7:00	7:07	7:17	7:26	7:35	35
7:15	7:23	7:33	7:43	7:52	37
7:30	7:38	7:48	7:58	8:07	37
7:45	7:53	8:03	8:13	8:22	37
8:00	8:08	8:18	8:28	8:37	37
8:15	8:22	8:32	8:41	8:50	35
8:30	8:37	8:46	8:55	9:03	33
8:50	8:57	9:06	9:14	9:21	31
9:10	9:17	9:26	9:34	9:41	31
9:40	9:46	9:55	10:02	10:09	29

To undertake this type of transitioning successfully requires a skilled scheduler with understanding of local conditions and operations.

Smoothing of Running Time Periods

A more sophisticated method of transitioning, known as running time smoothing, can also be applied. This type of transitioning recognizes that running times tend to change less in a tidal movement along a route, and more across the entire route at the same time. The running time periods apply not to the start time of the trip (as in traditional methods), but anywhere along the route that a trip may be at that time. The trip then immediately transitions to the next period.

This is shown diagrammatically below, for the 5:55 AM trip. The process effectively shifts the trip into the 6:00-6:59 running time period as soon as it hits 6:00 AM, regardless of where it is along the route. The 5:55 AM trips ends up with a total of 29 minutes running time (5 + 9 + 8 + 7) in this instance.

	5:00 to 5:59	6:00 to 6:59	7:00 to 8:29	8:30 to 9:29	9:30 to 14:59
A	-	-	-	-	-
B	5	7	8	7	6
C	8	9	10	9	9
D	7	8	10	8	7
E	6	7	9	7	7
Total	26	31	37	31	29

Applying the same running time periods to the same trips, but with smoothed periods, would result in the schedule below. The shading indicates that a given trip has moved into the next running time period.

A	B	C	D	E	Run Time
5:55	6:02	6:11	6:19	6:26	31
6:15	6:22	6:31	6:39	6:46	31
6:30	6:37	6:46	6:54	7:01	31
6:45	6:52	7:01	7:11	7:20	35
7:00	7:08	7:18	7:28	7:37	37
7:15	7:23	7:33	7:43	7:52	37
7:30	7:38	7:48	7:58	8:07	37
7:45	7:53	8:03	8:13	8:22	37
8:00	8:08	8:18	8:28	8:37	37
8:15	8:23	8:33	8:41	8:48	33
8:30	8:37	8:46	8:54	9:01	31
8:50	8:57	9:06	9:14	9:21	31
9:10	9:17	9:26	9:34	9:41	31
9:40	9:46	9:55	10:02	10:09	29
10:10	10:16	10:25	10:32	10:39	29

This approach automatically applies running time transitioning. It can be useful on long routes with significant running time changes, and often better reflects realistic operating conditions. In cases where there are large peak-direction traffic and passenger movements (typical of downtown-based services), this approach should be used with caution.

Running Time Myths

To summarize this discussion, some common scheduling myths are noted below:

- **Running time problems are all scheduling problems.** High variability of running times indicates a strong possibility that there are other factors at work and scheduling solutions alone cannot resolve the issue. In these cases the scheduler should identify the issues and work with operations staff to clarify what can be resolved at a scheduling level and what needs to be addressed at an operating level. This is often not an easy process and requires strong cooperation between scheduling and operations staff.

- **Lower on-time performance means insufficient running time.** In many cases early running may be as big an issue as late running. In other cases, running time may not be the issue at all.
- **Late running observations automatically mean that additional running time is required.** Operators adjust for the conditions they regularly experience. Therefore if scheduled running time is excessive, they may leave the terminal late to avoid running hot, resulting in late running observations along the route. The same applies in reverse. This is an example of the danger of using point checks or schedule adherence data as primary sources for running time adjustments.
- **Schedule deviation data can be used as a means of setting running times.** This is a broader statement of the previous two myths. Exception data is just that—data showing exceptions and deviations. Only elapsed running times can be used to analyze and revise running times. This cannot be stressed strongly enough.
- **Layover requirements are solely a function of trip length.** The length of a route does not necessarily indicate the need for more layover for schedule adherence purposes. Running time variability is not necessarily a function of route length, but of "typical" operating factors such as traffic congestion, patronage, operator variability, etc. Often (but not always) on longer routes, there is a "quiet" patch where the operator has a chance to make up lost time. Where longer layover is suggested for longer routes it is primarily related to operator rest time, not necessarily to run time variability.
- **Setting running times is a statistical process.** Many statistical and modeling approaches have been applied to running times. Often these approaches estimate the impacts of new running times based on existing data. However, these approaches fail to recognize an important consideration: scheduled running times influence operating running times and therefore one cannot simply apply a statistical approach and estimate outcomes. Statistical methods must be combined with local knowledge, visual presentation of data, and scheduler experience and skills to provide the "optimal" outcomes. In one city an automated AVL system that "reminded" operators running early or late was turned off, and run time data were collected. The results indicated significant running time differences when operators were not required to meet scheduled times. This phenomenon is also supported by the Los Angeles Metro Rapid experience with free running time.

A final point to note that can be overlooked even by the most experienced schedulers is to **always** calculate and review check operating speeds when proposed running times have been developed. This is the final "common sense" check of the type that schedulers should always be looking to apply to all aspects of the scheduling process.

LEVEL
3B

End of Schedule Building

Schedule Blocking continues on the next page.

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Chapter 4.
Schedule Blocking

4.1 Basic Blocking—The Importance of Blocking

LEVEL
1

In Chapter 3 we introduced the concept of **blocking**—breaking down a schedule into assignments for individual buses. These assignments are called **blocks** and consist of a series of trips that are “hooked” together and assigned to a single vehicle. The vehicle trips that are linked together as part of the block may serve multiple routes and may be operated by multiple operators. The block refers to the work assignment for a single vehicle for a single service workday.

Blocking is a main component of the scheduling process because it serves as the basis for the costs associated with operating the vehicle in revenue service and has a strong influence on the cost associated with work assignments for operators.

All blocking uses similar strategies and considerations. In this basic section, we will review the blocking of the Route 97 schedule in greater detail. The intermediate and advanced sections consider aspects of blocking that are common in more complex schedules.

Tip Blocking is not done in isolation—it is an intermediate step between writing a schedule and developing driver assignments, and must be done with the ultimate goal of developing efficient and “legal” driver work pieces.

blocking

The process in which trips are “hooked” together to form a vehicle assignment or block.

block

A vehicle (or train) assignment that includes the series of trips operated by each vehicle from the time it pulls out to the time it pulls in. A complete block includes a pull-out trip from the garage followed by one or (usually) more revenue trips and concluding with a pull-in trip back to the garage.

Blocking a Simple Schedule

The first step in the blocking process is to have a completed **master schedule** for each route or depot[1] to be blocked. In our case, the master schedule for Route 97 is shown on page 4-6.

The scheduler must be thoroughly knowledgeable of all work rules and policies related to blocking before beginning. However, as stressed earlier, a good scheduler keeps all aspects of scheduling in mind throughout the process. In developing blocks, it is also very important to have a thorough knowledge of the work rules regarding runcutting (assigning work to operators, see Chapter 5). Blocks that are "runcut friendly" optimize the efficiency of the entire scheduling process. Later sections of this chapter will explain the difference between blocks that are "runcut friendly" and blocks that are not.

Work rules and policies that are essential in blocking include:

- Layover and recovery time
- Layover locations
- Interlining policies

Layover and Recovery Time

The blocking process creates layovers and ensures that the bus has enough time in the round trip to stay on schedule. The terms "layover" and "recovery" refer to the time between trips, from the time a bus arrives at a terminal and the time the bus leaves the terminal to begin the next trip. While layover and recovery are often calculated as a single unit of time, in theory they are intended for two different purposes. Recovery time is time allotted by management to ensure that a bus can get back on schedule if it arrives at the terminal, or designated location, slightly behind schedule. A driver could be expected to reduce or eliminate their recovery time if they arrive at the terminal behind schedule and need to leave quickly to begin the next trip. **Layover time** is time negotiated by union rules and by agency practice to give drivers a break at the end of a trip. Layover time is paid time for operators and is considered part of the **platform time**.

master schedule

A document that displays all time points and trips on a route. Usually includes run numbers, and block numbers, and pull-in and pull-out times. Used interchangeably in this manual with "headway sheet."

layover time

The time between the scheduled arrival and departure of a vehicle at a transit terminal. Often used interchangeably with "recovery time," although technically layover time is rest time for the operator between trips while recovery time is time built into the schedule to ensure an on-time departure for the next trip. In this manual, layover and recovery are calculated together and the total time between trips is referred to as "layover."

platform time

Platform time, a phrase derived from the early 20th century days when motormen and conductors operated from the "platform" of a streetcar, platform time includes all time when the operator is operating the vehicle. Layover time and pull-in and pull-out time are part of platform time, but report allowance and clear allowance, and travel time (unless part of a pull-in or pull-out) are not. Similarly, platform miles include all miles traveled while the operator is operating the vehicle. Also known as "vehicle hours."

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[1] In the advanced section the topic of interlining will be discussed. It should be noted now that block interlining can be applied not just at the route level but among routes, at the garage level, as well.

Tip Understanding your properties rules on layover and recovery are essential to blocking and schedule making. Properties with less flexible rules for calculating layover and recovery times will inevitably have less efficient schedules, as one minute of layover often makes the difference between adding a bus to a route or not.

While layover and recovery time are theoretically different, the fact is that this is time applied at the end of a trip, paid to the operator, and added to the time required to “turn the bus” and complete the trip. Layover and recovery time are often calculated together and thought of as just one unit of time. In this manual, we will calculate layover and recovery together and will refer to the total time between trips as “layover.”

Layover policy may be spelled out in the labor agreement, based on formal agency standards, or based on informal practices. Work rules vary across transit properties. Required layover typically varies from none at all to 10% to 15% of the trip running time. Ten percent has been a longtime standard within the industry. Some agencies specified either 10% of running time or five minutes, whichever is greater.

To optimize the blocking process, the scheduler must know whether the agency’s layover policy represents a hard and fast rule that must be followed in all cases or a guideline that can be “bent” to optimize the blocking process and reduce peak bus requirements. Some agencies allow policy exceptions during peak hours only as long as the exceptions do not involve consecutive trips.

Given the potential for delays that cannot be reliably anticipated, such as traffic incidents, wheelchair boardings and alightings (helped somewhat by the use of ramps on low floor buses), and bicycle rack activity, many schedulers today provide more than 10% layover. Fifteen % is not unusual, and a number of systems schedule layover time as high as 20% of running time.

Layover time is added to the round-trip running time in order to plan for the number of buses in the schedule. Where wider headways (20 to 30 minutes) are the norm, the amount of layover time in the schedule tends to be greater also, since there are fewer multiples of a 20- or 30-minute headway. Many systems operate a pulse schedule where everything meets at a central location or at an outlying transit center. In a pulse system, longer routes get correspondingly less layover. Linking long routes that are tight for time with shorter routes where layover is plentiful is an excellent strategy in these circumstances.

Layover Location

Many agencies limit the locations where layover can be taken. In a pulse system where many routes meet at a central location, layover may be scheduled at this location to facilitate transfers or may be scheduled at the outer ends of the route to avoid congestion. Layover time is sometimes required at the end of each one-way trip, requiring a layover location at both ends of the route, but more often is applied to each round trip. A major factor in selecting layover locations is the availability of operator facilities.

Layover time must be scheduled in a safe location where a bus can be parked without impeding traffic. Layover is usually taken at the end of the route where it does not inconvenience passengers. Routes with a one-way loop at one or both ends create challenges for identifying a layover location, since through ridership along the loop means that some passengers will experience a delay. Layover time may also be assigned at key mid-route transfer points (such as a rail station or major transfer point).

Ideally, the layover should occur at a location that allows the operator to safely leave the bus, use the restroom, stretch his/her legs, and get away from the bus for a minute or two. Routes with a one-way loop at one or both ends create challenges for identifying a layover location, since riders will be on the bus throughout the loop and some passengers will experience a delay. Layover time may also be assigned at key mid-route transfer points (such as a rail station or major transfer point).

Interlining and Through-routing

Sometimes, trips that come into the end of the line are not simply sent back out on the same route but can be **"interlined"** or hooked to other routes serving that terminal or another nearby location. Interlining is most often done to optimize blocking, although it can be a convenience to passengers.

For example, if many passenger trips originating on one route are destined for locations along a second route that shares a common terminal location, interlining will allow those passengers to reach their destination without transferring to another vehicle. At some systems, such activity is the precursor to merging the two routes into one.

Another application of interlining is to match up **school trips** in the afternoon with trips at the start of evening peak trips. Such matching is invaluable for saving PM pull-outs. The process is usually not applied in the AM because of the overlap of **school service** with AM peak service. Bus savings are always a priority, but interlining is also highly useful for saving bus hours, which ultimately saves platform costs and even operators.

Tip Layover is rarely done in the middle of a route when passengers are on board, unless there is a timed meet at a major stop on the route. Layover is applied at the end of the route so that passengers are not required to "sit through" a layover, and so that drivers can have a layover that is free from passenger responsibilities. Some layover time is often added to a timed meet location to ensure that the meet will occur even if one bus is behind schedule. Layover locations are sensitive because they require a location where a bus can "sit" safely for a period of time.

interlining

The use of the same vehicle on a block operating on more than one route with the same operator, without returning to the garage during route changes.

school trips or school service

Additional scheduled trips at school bell times to accommodate the heavy loads associated with student ridership along a route. School trips are typically inserted into the schedule for no longer than necessary to address ridership demand. As with other service, these trips are open to the public and are included on public timetables.

Tip While it might be tempting to minimize layover in all cases, remember that layover serves an important purpose—it is designed to get trips to start on time and can be one of the most important factors in reliability.

through-routing

A form of interlining in which a vehicle switches from inbound service on one route to outbound service on another route while continuing in service throughout the day.

In a radial transit network with timed meets at the central locations, interlining long routes that are tight for time with shorter routes where layover is plentiful is an excellent strategy. In this case, interlining guards against the domino effect of a long route arriving later and later each hour. It also ensures adequate layover time for each operator, an important factor in operator-friendly assignments.

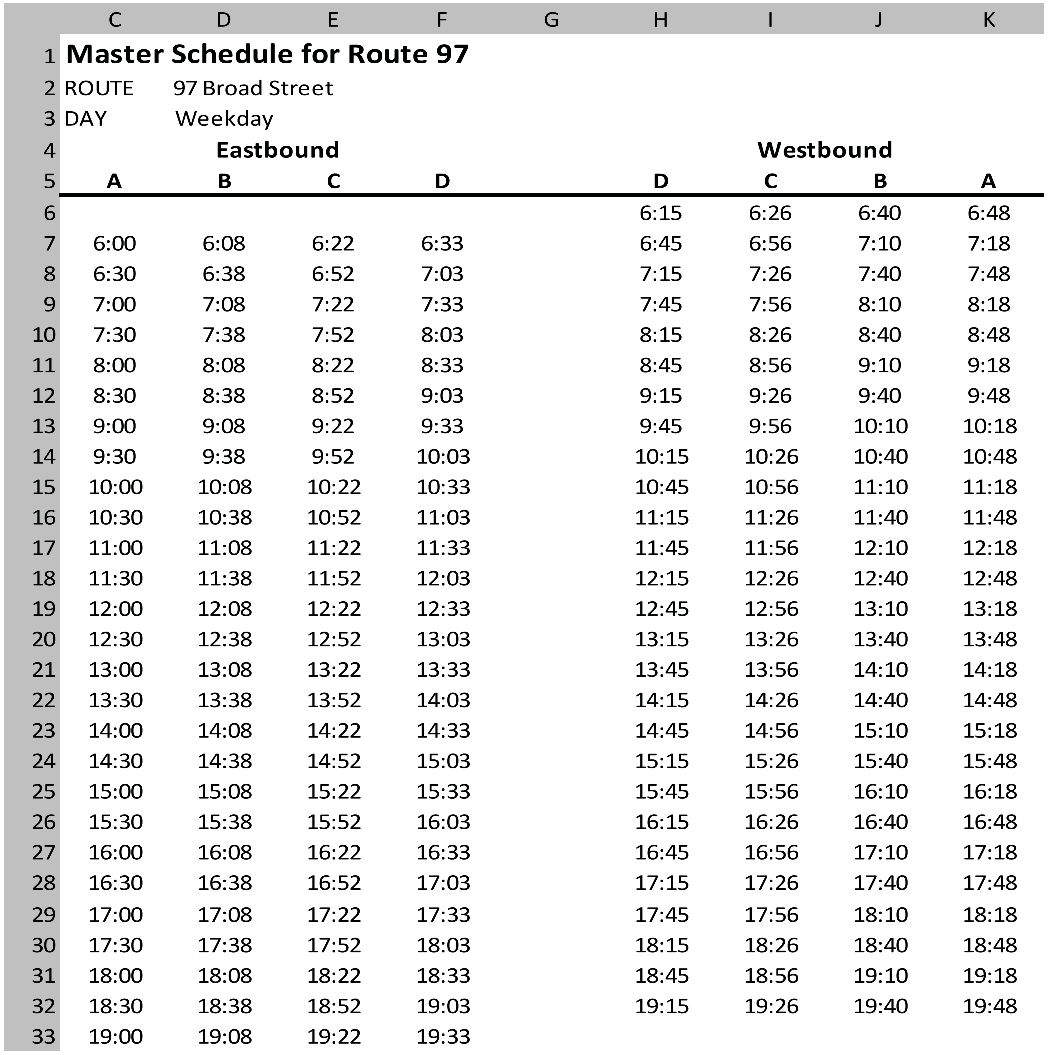
Vehicles may travel between one route and another only once or only occasionally throughout the day. For example, a PM pull-out may first do a school-related trip on Route X and then operate on Route Y. Another case might involve a vehicle providing morning peak service on one route and then operating on another route in the midday period.

It is also possible for a vehicle to alternate trips between two or more routes throughout the day. If only two routes are involved, this form of regular interlining is often referred to as **"through-routing."** "Interlining" and "through-routing" tend to be used interchangeably, but through-routing is the process of tying together routes, especially radial routes which serve a central downtown location, to form one long route from one end of town to another via downtown. Each trip throughout the day arrives as Route A and leaves as Route B. Both routes may even carry the same route number. Through-routing can reduce the number of buses by eliminating any duplication of two unconnected routes that would otherwise terminate downtown, provide through passengers with a one-seat ride, reduce the need for layover space, and simplify routing by reducing the number of turns required.

The amount of interlining at any transit property is often a matter of policy. One of the transit systems that served as a case study makes it a policy to interline as much service as possible. The agency's interest is for drivers to work as many routes as possible during their run. It helps make the day more interesting, familiarizes the drivers with more of the system, and at the same time saves enough buses to make the more complex blocking arrangement worth the extra time it takes to set up.

Basic Blocking Exercise

With an understanding of the basic concepts of blocking, we are ready to block Route 97. The master schedule for Route 97 was developed in the basic section of the previous chapter on schedule building, and is shown below. The schedule provides service every 30 minutes from the first eastbound trip at 6:00 AM to the last westbound trip at 7:15 PM. Running times are consistent (i.e., do not change) throughout the day.



	C	D	E	F	G	H	I	J	K
1	**Master Schedule for Route 97**								
2	ROUTE	97 Broad Street							
3	DAY	Weekday							
4		**Eastbound**					**Westbound**		
5	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**
6						6:15	6:26	6:40	6:48
7	6:00	6:08	6:22	6:33		6:45	6:56	7:10	7:18
8	6:30	6:38	6:52	7:03		7:15	7:26	7:40	7:48
9	7:00	7:08	7:22	7:33		7:45	7:56	8:10	8:18
10	7:30	7:38	7:52	8:03		8:15	8:26	8:40	8:48
11	8:00	8:08	8:22	8:33		8:45	8:56	9:10	9:18
12	8:30	8:38	8:52	9:03		9:15	9:26	9:40	9:48
13	9:00	9:08	9:22	9:33		9:45	9:56	10:10	10:18
14	9:30	9:38	9:52	10:03		10:15	10:26	10:40	10:48
15	10:00	10:08	10:22	10:33		10:45	10:56	11:10	11:18
16	10:30	10:38	10:52	11:03		11:15	11:26	11:40	11:48
17	11:00	11:08	11:22	11:33		11:45	11:56	12:10	12:18
18	11:30	11:38	11:52	12:03		12:15	12:26	12:40	12:48
19	12:00	12:08	12:22	12:33		12:45	12:56	13:10	13:18
20	12:30	12:38	12:52	13:03		13:15	13:26	13:40	13:48
21	13:00	13:08	13:22	13:33		13:45	13:56	14:10	14:18
22	13:30	13:38	13:52	14:03		14:15	14:26	14:40	14:48
23	14:00	14:08	14:22	14:33		14:45	14:56	15:10	15:18
24	14:30	14:38	14:52	15:03		15:15	15:26	15:40	15:48
25	15:00	15:08	15:22	15:33		15:45	15:56	16:10	16:18
26	15:30	15:38	15:52	16:03		16:15	16:26	16:40	16:48
27	16:00	16:08	16:22	16:33		16:45	16:56	17:10	17:18
28	16:30	16:38	16:52	17:03		17:15	17:26	17:40	17:48
29	17:00	17:08	17:22	17:33		17:45	17:56	18:10	18:18
30	17:30	17:38	17:52	18:03		18:15	18:26	18:40	18:48
31	18:00	18:08	18:22	18:33		18:45	18:56	19:10	19:18
32	18:30	18:38	18:52	19:03		19:15	19:26	19:40	19:48
33	19:00	19:08	19:22	19:33					

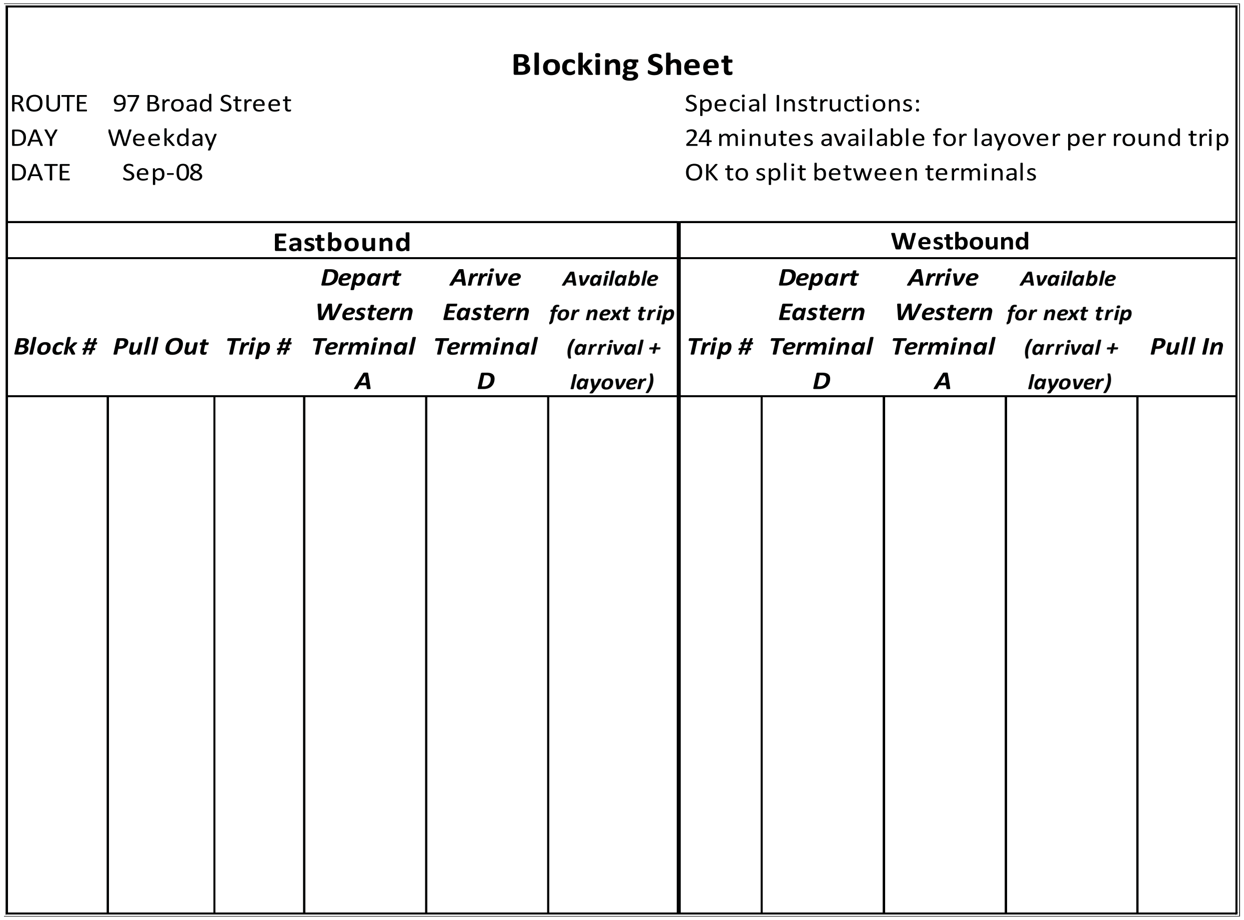
Applicable work rules include the following:

- The minimum layover time is 10% of round-trip running time.
- Layover time may be taken at either terminal and may be divided in any way between the two terminals as long as the total layover time for any round trip is at least 10% of round-trip running time.
- No interlining will take place, because only one route is being blocked in this example.
- No other work rules apply.

A **blocking sheet** is often used to track blocks as they are created. A sample blocking sheet is shown below.

blocking sheet

A sheet listing all blocks that also includes the trips and times for all trips within each block.



Blocking Sheet

ROUTE 97 Broad Street
DAY Weekday
DATE Sep-08

Special Instructions:
24 minutes available for layover per round trip
OK to split between terminals

Eastbound						Westbound				
Block #	***Pull Out***	***Trip #***	***Depart Western Terminal A***	***Arrive Eastern Terminal D***	***Available for next trip (arrival + layover)***	***Trip #***	***Depart Eastern Terminal D***	***Arrive Western Terminal A***	***Available for next trip (arrival + layover)***	***Pull In***

Pull-out refers to the time that a vehicle is scheduled to leave the garage or depot and travel to the point on the route where revenue service begins. Pull-in refers to the time that the vehicle is scheduled to arrive at the garage/depot after completing revenue service. For Route 97, **pull-out times** are listed in the Pull-out and Pull-in Allowance table shown below.

Route 97 Pull-out and Pull-in Allowances

Terminal	Pull-out	Pull-in
A	Weekday: 0:10 Sat/Sun: no service	Weekday: 0:10 Sat/Sun: no service
B	Weekday: 0:20 Sat/Sun: no service	Weekday: 0:20 Sat/Sun: no service

Our work rules require a minimum layover time of 10% of the total round-trip running time. The running time is 33 minutes in each direction, or 66 minutes for a round trip. Thus, 66 x 10% = 6.6, rounded up to 7 minutes of layover time. Recall in Chapter 3 that we decided on a 30-minute headway, resulting in 24 minutes of layover time per round trip. So, there should be no problem meeting minimum layover requirements.

One final note before we get down to work relates to block numbering conventions. Transit agencies use a variety of numbering conventions for blocks. One of the most common is to use a four-digit number, where the first two digits are the route number and the second two digits are the block number. This guarantees that each block will have a unique block number. For Route 97, the first block number would be 9701.

Different systems have their own style of numbering blocks. Some like to go in strict time out order, while others prefer to keep block numbers in order during the day. The concept of the block number serves two purposes: (1) to keep track of the blocks while building the schedule and constructing runs and (2) to inform on-street supervision of the positive identification of a particular trip (not always obvious on a route with a 10-minute or better headway). Because of the latter, many prefer numbering blocks in order, and this will be the convention we follow for Route 97.

The Blocking Process for Route 97

The first trip on the master schedule sheet is eastbound at 6:00 AM. The pull-in and pull-out allowance table indicates that the pull-out time to point A is 10 minutes, so the first block, 9701, pulls out from the garage at 5:50 AM and travels without passengers (deadheads) to the western terminal at A in time to begin service at 6:00 AM. Block 9701 arrives at the eastern terminal (D) at 6:33. The next available westbound trip is at 6:45, allowing 12 minutes of layover time at

pull-out time

The time the vehicle spends traveling from the garage to the route. Pull-out time is included in vehicle hours, but not in revenue hours. Collectively, pull-in time and pull-out time are also known as pull time and are components of deadhead miles.

Tip Layover time is almost always rounded up to the nearest minute.

Tip Blocks must always include a pull-out time (the time the bus is scheduled to leave the garage) and a pull-in time (the time the bus should arrive back at the garage).

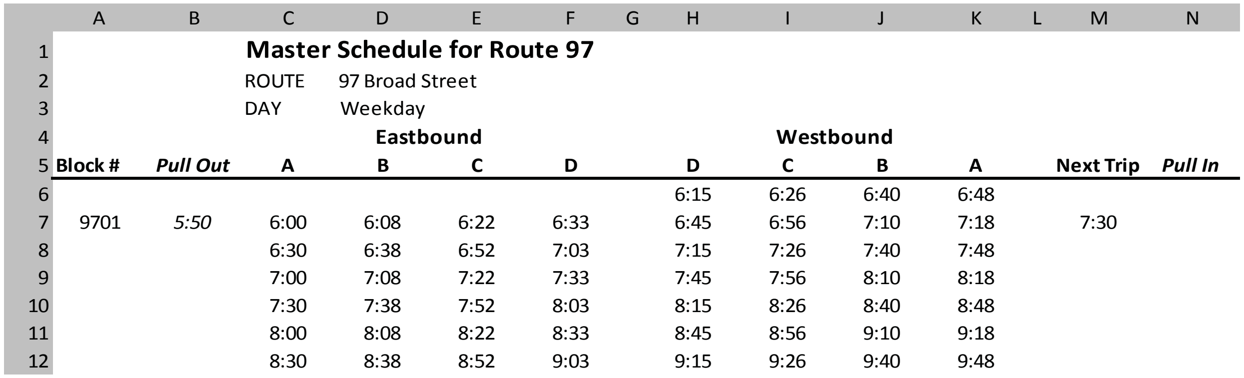
The amount of time required to travel from the garage to the route and to return to the garage will vary by route and terminal.

pull-in time

The time the vehicle spends traveling from the route to the garage. Pull-in time is included in vehicle hours, but not in revenue hours. Collectively, pull-in time and pull-out time are also known as pull time and are components of deadhead miles.

D. This trip reaches A at 7:18 and, after 12 minutes of layover, can make its next eastbound trip at 7:30.

Note below on the master schedule worksheet that we have inserted two columns to the left of Point A for the block number and the pull-out time. We have added two columns on the right, listing the next trip time leaving Point A and the **pull-in time**. We have also lined up the trips arriving and departing at Point D so that the round trip for a given block is in the same row. This helps in following the progress of a block throughout the day, as does listing the next trip time on the right-hand side. We have entered all the information noted above in this spreadsheet.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			**Master Schedule for Route 97**											
2			ROUTE	97 Broad Street										
3			DAY	Weekday										
4				**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	***Pull In***
6								6:15	6:26	6:40	6:48			
7	9701	*5:50*	6:00	6:08	6:22	6:33		6:45	6:56	7:10	7:18		7:30	
8			6:30	6:38	6:52	7:03		7:15	7:26	7:40	7:48			
9			7:00	7:08	7:22	7:33		7:45	7:56	8:10	8:18			
10			7:30	7:38	7:52	8:03		8:15	8:26	8:40	8:48			
11			8:00	8:08	8:22	8:33		8:45	8:56	9:10	9:18			
12			8:30	8:38	8:52	9:03		9:15	9:26	9:40	9:48			

It is helpful to track the trip numbers for each block on either a copy of the master schedule or on the blocking sheet. Below are the entries on the blocking sheet for the pull-out and the first trips.

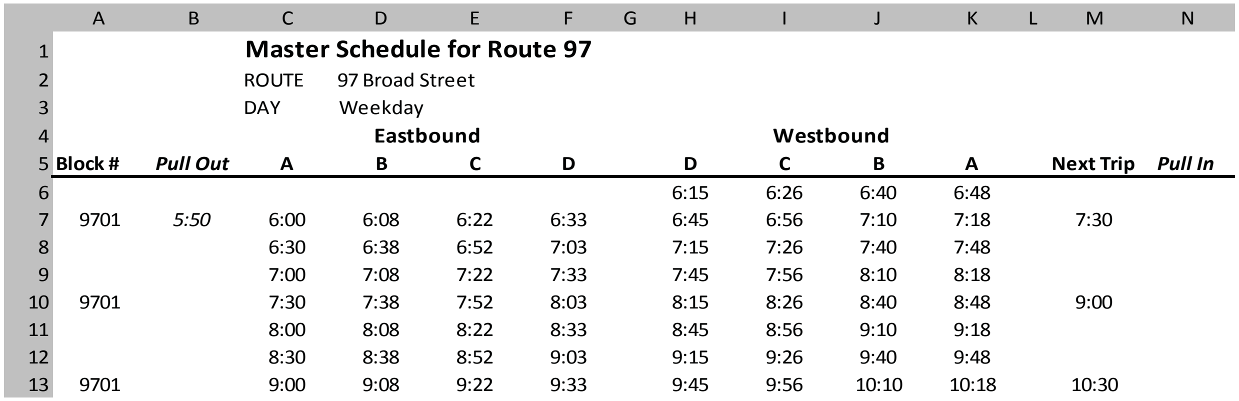
Blocking Sheet

ROUTE 97 Broad Street
DAY Weekday
DATE Sep-08

Special Instructions:
24 minutes available for layover per round trip
OK to split between terminals

Eastbound						**Westbound**				
Block #	***Pull Out***	***Trip #***	***Depart Western Terminal A***	***Arrive Eastern Terminal D***	***Available for next trip (arrival + layover)***	***Trip #***	***Depart Eastern Terminal D***	***Arrive Western Terminal A***	***Available for next trip (arrival + layover)***	***Pull In***
9701	5:50	01	6:00	6:33	6:45	02	6:45	7:18	7:30	

The blocking process continues by hooking more trips on to 9701. Use of color coding on spreadsheets to follow a block through the day is extremely helpful. Since this example is in black and white, we will simply indicate the block number and next trip on the spreadsheet. We show the next two round trips for block 9701 below.

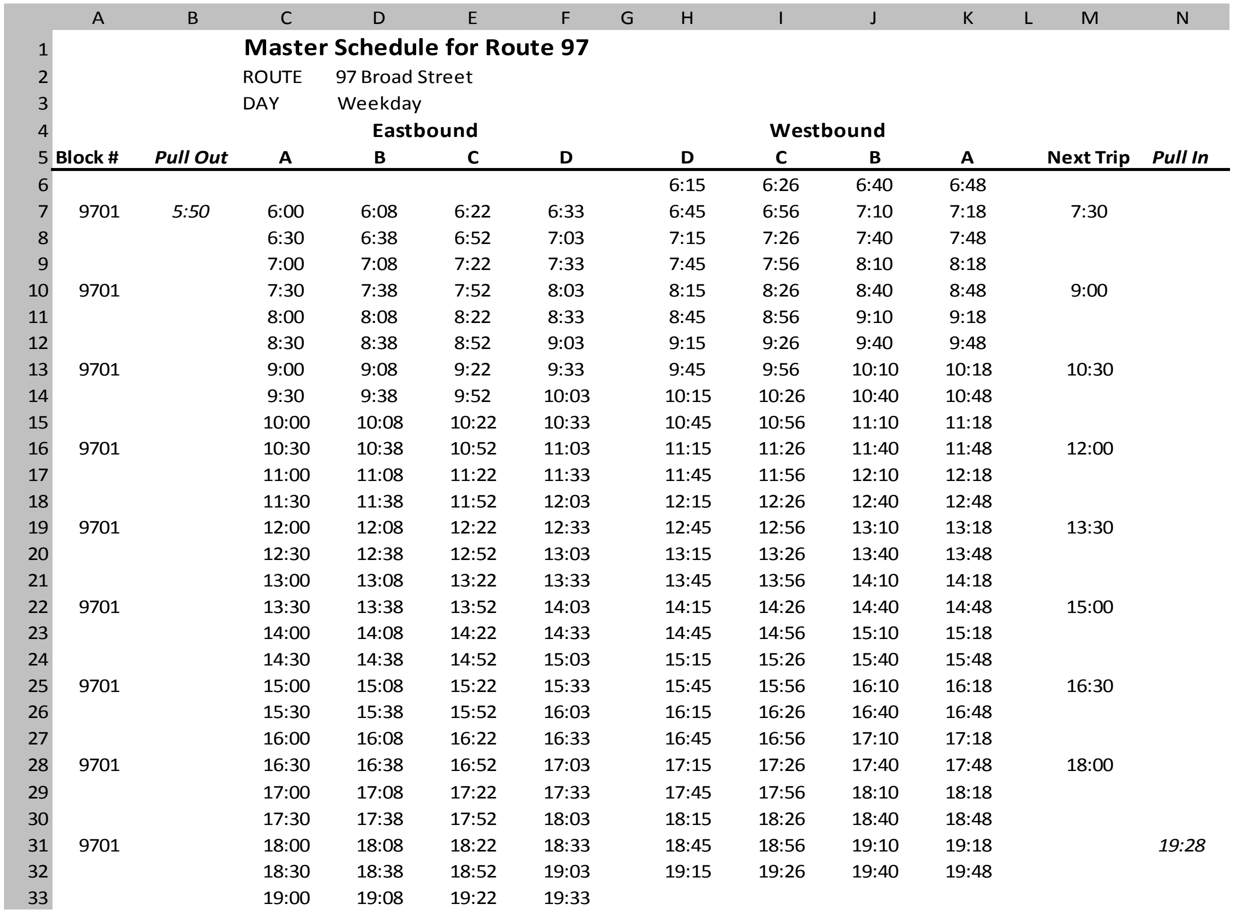


	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			**Master Schedule for Route 97**											
2			ROUTE	97 Broad Street										
3			DAY	Weekday										
4				**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	***Pull In***
6								6:15	6:26	6:40	6:48			
7	9701	*5:50*	6:00	6:08	6:22	6:33		6:45	6:56	7:10	7:18		7:30	
8			6:30	6:38	6:52	7:03		7:15	7:26	7:40	7:48			
9			7:00	7:08	7:22	7:33		7:45	7:56	8:10	8:18			
10	9701		7:30	7:38	7:52	8:03		8:15	8:26	8:40	8:48		9:00	
11			8:00	8:08	8:22	8:33		8:45	8:56	9:10	9:18			
12			8:30	8:38	8:52	9:03		9:15	9:26	9:40	9:48			
13	9701		9:00	9:08	9:22	9:33		9:45	9:56	10:10	10:18		10:30	

Block 9701 makes the 7:30 eastbound trip and the 8:15 westbound trip. The next available trip at A when it arrives at 8:48 is the 9:00 trip. So we note that block 9701 will make this trip and the return trip westbound at 9:45.

travel time
Paid time allowed for an operator to travel between the garage and a relief location. If the travel is for relief purposes only and is not part of a pull-in or pull-out, then travel time is not included in platform time.

Now continue this process of hooking trips for the remainder of the day. Your spreadsheet will look like this:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			**Master Schedule for Route 97**											
2			ROUTE	97 Broad Street										
3			DAY	Weekday										
4			**Eastbound**					**Westbound**						
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	***Pull In***
6								6:15	6:26	6:40	6:48			
7	9701	*5:50*	6:00	6:08	6:22	6:33		6:45	6:56	7:10	7:18		7:30	
8			6:30	6:38	6:52	7:03		7:15	7:26	7:40	7:48			
9			7:00	7:08	7:22	7:33		7:45	7:56	8:10	8:18			
10	9701		7:30	7:38	7:52	8:03		8:15	8:26	8:40	8:48		9:00	
11			8:00	8:08	8:22	8:33		8:45	8:56	9:10	9:18			
12			8:30	8:38	8:52	9:03		9:15	9:26	9:40	9:48			
13	9701		9:00	9:08	9:22	9:33		9:45	9:56	10:10	10:18		10:30	
14			9:30	9:38	9:52	10:03		10:15	10:26	10:40	10:48			
15			10:00	10:08	10:22	10:33		10:45	10:56	11:10	11:18			
16	9701		10:30	10:38	10:52	11:03		11:15	11:26	11:40	11:48		12:00	
17			11:00	11:08	11:22	11:33		11:45	11:56	12:10	12:18			
18			11:30	11:38	11:52	12:03		12:15	12:26	12:40	12:48			
19	9701		12:00	12:08	12:22	12:33		12:45	12:56	13:10	13:18		13:30	
20			12:30	12:38	12:52	13:03		13:15	13:26	13:40	13:48			
21			13:00	13:08	13:22	13:33		13:45	13:56	14:10	14:18			
22	9701		13:30	13:38	13:52	14:03		14:15	14:26	14:40	14:48		15:00	
23			14:00	14:08	14:22	14:33		14:45	14:56	15:10	15:18			
24			14:30	14:38	14:52	15:03		15:15	15:26	15:40	15:48			
25	9701		15:00	15:08	15:22	15:33		15:45	15:56	16:10	16:18		16:30	
26			15:30	15:38	15:52	16:03		16:15	16:26	16:40	16:48			
27			16:00	16:08	16:22	16:33		16:45	16:56	17:10	17:18			
28	9701		16:30	16:38	16:52	17:03		17:15	17:26	17:40	17:48		18:00	
29			17:00	17:08	17:22	17:33		17:45	17:56	18:10	18:18			
30			17:30	17:38	17:52	18:03		18:15	18:26	18:40	18:48			
31	9701		18:00	18:08	18:22	18:33		18:45	18:56	19:10	19:18			*19:28*
32			18:30	18:38	18:52	19:03		19:15	19:26	19:40	19:48			
33			19:00	19:08	19:22	19:33								

Note that when 9701 completes the 18:45 westbound trip at 19:18, it has no trip to hook to and so it is time to return to the garage. The pull-out and pull-in allowance sheet indicates 10 minutes of **travel time** from point A to the garage, so the pull-in time will be 19:18 + 0:10 =19:28.

The blocking sheet now summarizes the information for all trips on block 9701 and looks like this:

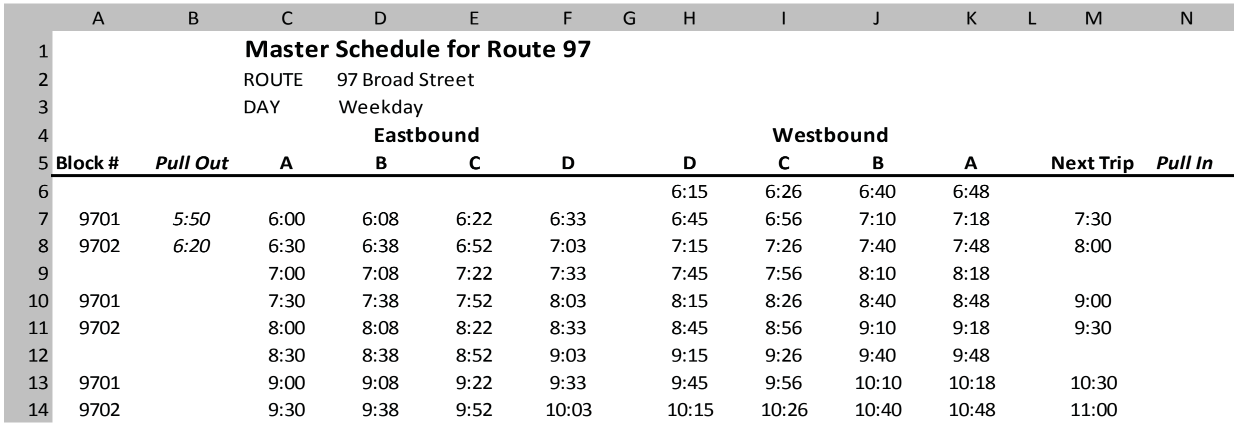
Blocking Sheet

ROUTE 97 Broad Street
DAY Weekday
DATE Sep-08

Special Instructions:
24 minutes available for layover per round trip
OK to split between terminals

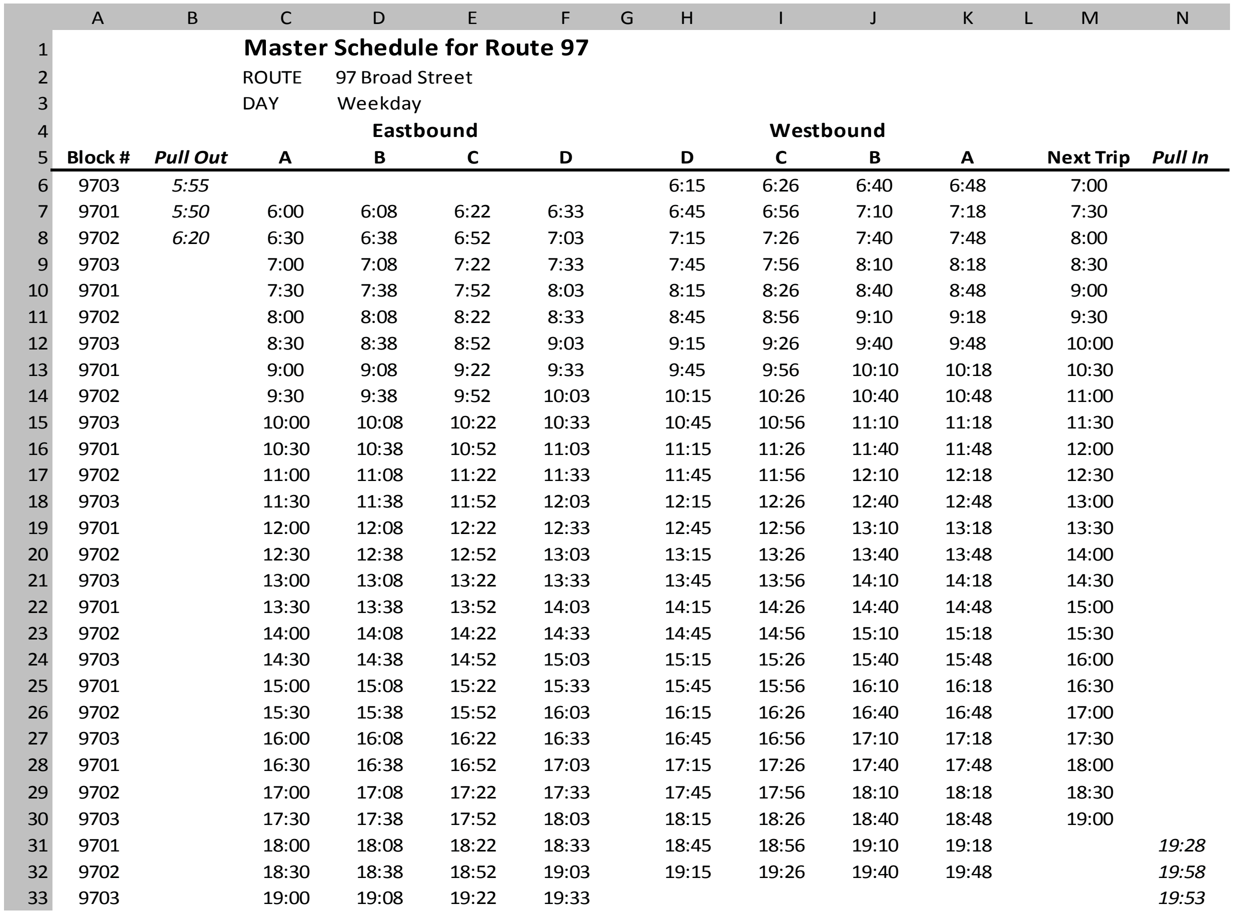
Eastbound						Westbound				
Block #	***Pull Out***	***Trip #***	***Depart Western Terminal A***	***Arrive Eastern Terminal D***	***Available for next trip (arrival + layover)***	***Trip #***	***Depart Eastern Terminal D***	***Arrive Western Terminal A***	***Available for next trip (arrival + layover)***	***Pull In***
9701	5:50	01	6:00	6:33	6:45	02	6:45	7:18	7:30	
9701		03	7:30	8:03	8:15	04	8:15	8:48	9:00	
9701		05	9:00	9:33	9:45	06	9:45	10:18	10:30	
9701		07	10:30	11:03	11:15	08	11:15	11:48	12:00	
9701		09	12:00	12:33	12:45	10	12:45	13:18	13:30	
9701		11	13:30	14:03	14:15	12	14:15	14:48	15:00	
9701		13	15:00	15:33	15:45	14	15:45	16:18	16:30	
9701		15	16:30	17:03	17:15	16	17:15	17:48	18:00	
9701		17	18:00	18:33	18:45	18	18:45	19:18		19:28

Next, we add Block 9702. As noted earlier in the discussion of block numbering, we will keep the blocks in numerical order throughout the day, so Block 9702 should always follow 9701. Its first trip will thus be eastbound at 6:30, requiring a pull-out time of 6:20. The example below shows the first few trips of 9702 filled in on the spreadsheet.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			**Master Schedule for Route 97**											
2			ROUTE	97 Broad Street										
3			DAY	Weekday										
4				**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	***Pull In***
6								6:15	6:26	6:40	6:48			
7	9701	*5:50*	6:00	6:08	6:22	6:33		6:45	6:56	7:10	7:18		7:30	
8	9702	*6:20*	6:30	6:38	6:52	7:03		7:15	7:26	7:40	7:48		8:00	
9			7:00	7:08	7:22	7:33		7:45	7:56	8:10	8:18			
10	9701		7:30	7:38	7:52	8:03		8:15	8:26	8:40	8:48		9:00	
11	9702		8:00	8:08	8:22	8:33		8:45	8:56	9:10	9:18		9:30	
12			8:30	8:38	8:52	9:03		9:15	9:26	9:40	9:48			
13	9701		9:00	9:08	9:22	9:33		9:45	9:56	10:10	10:18		10:30	
14	9702		9:30	9:38	9:52	10:03		10:15	10:26	10:40	10:48		11:00	

We continue 9702 throughout the day until its pull-in time at 19:58. Then we add block 9703. Note that this block pulls out to D, not A, so we need to check our allowance table. Instead of the 10 minutes of pull-out time to point A, 9703 requires 20 minutes to point D, so pull-out time is 20 minutes earlier than 6:15, or 5:55. The pull-in is also from D, not A, and requires 20 minutes. The pull-in time for 9703 is 19:53, as shown in the completed blocked schedule below.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			**Master Schedule for Route 97**											
2			ROUTE	97 Broad Street										
3			DAY	Weekday										
4				**Eastbound**					**Westbound**					
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	***Pull In***
6	9703	*5:55*						6:15	6:26	6:40	6:48		7:00	
7	9701	*5:50*	6:00	6:08	6:22	6:33		6:45	6:56	7:10	7:18		7:30	
8	9702	*6:20*	6:30	6:38	6:52	7:03		7:15	7:26	7:40	7:48		8:00	
9	9703		7:00	7:08	7:22	7:33		7:45	7:56	8:10	8:18		8:30	
10	9701		7:30	7:38	7:52	8:03		8:15	8:26	8:40	8:48		9:00	
11	9702		8:00	8:08	8:22	8:33		8:45	8:56	9:10	9:18		9:30	
12	9703		8:30	8:38	8:52	9:03		9:15	9:26	9:40	9:48		10:00	
13	9701		9:00	9:08	9:22	9:33		9:45	9:56	10:10	10:18		10:30	
14	9702		9:30	9:38	9:52	10:03		10:15	10:26	10:40	10:48		11:00	
15	9703		10:00	10:08	10:22	10:33		10:45	10:56	11:10	11:18		11:30	
16	9701		10:30	10:38	10:52	11:03		11:15	11:26	11:40	11:48		12:00	
17	9702		11:00	11:08	11:22	11:33		11:45	11:56	12:10	12:18		12:30	
18	9703		11:30	11:38	11:52	12:03		12:15	12:26	12:40	12:48		13:00	
19	9701		12:00	12:08	12:22	12:33		12:45	12:56	13:10	13:18		13:30	
20	9702		12:30	12:38	12:52	13:03		13:15	13:26	13:40	13:48		14:00	
21	9703		13:00	13:08	13:22	13:33		13:45	13:56	14:10	14:18		14:30	
22	9701		13:30	13:38	13:52	14:03		14:15	14:26	14:40	14:48		15:00	
23	9702		14:00	14:08	14:22	14:33		14:45	14:56	15:10	15:18		15:30	
24	9703		14:30	14:38	14:52	15:03		15:15	15:26	15:40	15:48		16:00	
25	9701		15:00	15:08	15:22	15:33		15:45	15:56	16:10	16:18		16:30	
26	9702		15:30	15:38	15:52	16:03		16:15	16:26	16:40	16:48		17:00	
27	9703		16:00	16:08	16:22	16:33		16:45	16:56	17:10	17:18		17:30	
28	9701		16:30	16:38	16:52	17:03		17:15	17:26	17:40	17:48		18:00	
29	9702		17:00	17:08	17:22	17:33		17:45	17:56	18:10	18:18		18:30	
30	9703		17:30	17:38	17:52	18:03		18:15	18:26	18:40	18:48		19:00	
31	9701		18:00	18:08	18:22	18:33		18:45	18:56	19:10	19:18			*19:28*
32	9702		18:30	18:38	18:52	19:03		19:15	19:26	19:40	19:48			*19:58*
33	9703		19:00	19:08	19:22	19:33								*19:53*

The completed blocking sheet is shown below.

Blocking Sheet

ROUTE 97 Broad Street
DAY Weekday
DATE Sep-08

Special Instructions:
24 minutes available for layover per round trip
OK to split between terminals

Eastbound						Westbound				
Block #	***Pull Out***	***Trip #***	***Depart Western Terminal A***	***Arrive Eastern Terminal D***	***Available for next trip (arrival + layover)***	***Trip #***	***Depart Eastern Terminal D***	***Arrive Western Terminal A***	***Available for next trip (arrival + layover)***	***Pull In***
9701	5:50	01	6:00	6:33	6:45	02	6:45	7:18	7:30	
9701		03	7:30	8:03	8:15	04	8:15	8:48	9:00	
9701		05	9:00	9:33	9:45	06	9:45	10:18	10:30	
9701		07	10:30	11:03	11:15	08	11:15	11:48	12:00	
9701		09	12:00	12:33	12:45	10	12:45	13:18	13:30	
9701		11	13:30	14:03	14:15	12	14:15	14:48	15:00	
9701		13	15:00	15:33	15:45	14	15:45	16:18	16:30	
9701		15	16:30	17:03	17:15	16	17:15	17:48	18:00	
9701		17	18:00	18:33	18:45	18	18:45	19:18		19:28
9702	6:20	01	6:30	7:03	7:15	02	7:15	7:48	8:00	
9702		03	8:00	8:33	8:45	04	8:45	9:18	9:30	
9702		05	9:30	10:03	10:15	06	10:15	10:48	11:00	
9702		07	11:00	11:33	11:45	08	11:45	12:18	12:30	
9702		09	12:30	13:03	13:15	10	13:15	13:48	14:00	
9702		11	14:00	14:33	14:45	12	14:45	15:18	15:30	
9702		13	15:30	16:03	16:15	14	16:15	16:48	17:00	
9702		15	17:00	17:33	17:45	16	17:45	18:18	18:30	
9702		17	18:30	19:03	19:15	18	19:15	19:48		19:58
9703	5:55					01	6:15	6:48	7:00	
9703		02	7:00	7:33	7:45	03	7:45	8:18	8:30	
9703		04	8:30	9:03	9:15	05	9:15	9:48	10:00	
9703		06	10:00	10:33	10:45	07	10:45	11:18	11:30	
9703		08	11:30	12:03	12:15	09	12:15	12:48	13:00	
9703		10	13:00	13:33	13:45	11	13:45	14:18	14:30	
9703		12	14:30	15:03	15:15	13	15:15	15:48	16:00	
9703		14	16:00	16:33	16:45	15	16:45	17:18	17:30	
9703		16	17:30	18:03	18:15	17	18:15	18:48	19:00	
9703		18	19:00	19:33						19:53

Now that we have been through the basic blocking process, questions such as the following may arise.

How is layover time related to costs?

Excessive layover time increases the number of vehicles and operators required on a given route. Recall that we calculate the number of vehicles required using the following formula:

$$\text{\# Vehicles} = \frac{\text{Cycle time}}{\text{Headway}}$$

where cycle time equals the round-trip running time plus layover time and headway is the time between trips.

For example, if a route has a round-trip running time of 54 minutes plus 6 minutes for layover and a headway of 10 minutes, then the formula shows a need for 6 vehicles:

$$\text{\# Vehicles} = \frac{(54+6)=60}{10} = 6$$

However, if the layover time is increased to 16 minutes, then the number of vehicles needed also increases:

$$\text{\# Vehicles} = \frac{(54+16)=70}{10} = 7$$

Obviously, a layover of 6 minutes versus 16 minutes is more economical in terms of fewer vehicles and, most likely, fewer operators.

Is there any benefit to having slightly excessive layover time?

As noted in Chapter 3 (Schedule Building), extra layover time may be assigned when clockface headways are desired, as in the Route 97 example. Also, timed transfers sometimes result in the need for extra layover time to ensure that passengers on trips arriving a few minutes behind schedule can still make their connections. Schedule building and blocking often involve a balancing of cost-effectiveness and customer service needs.

In cases where excessive layover time does exist after a trip, it may be possible to hook this trip with another trip. These are opportunities that schedulers continually evaluate.

Do many schedules maintain a consistent headway throughout the day?

Busy routes on major travel corridors typically have shorter headways (i.e., more frequent service) in the peak hours. Routes serving less busy areas are more likely to maintain a consistent headway throughout the day. Even on these routes, however, the last trip or two of the day is often inconsistent for a variety of reasons. One important reason to delay the start time of the last trips on a route is to allow the maximum number of passengers to catch the final trip(s). The last trip of the day often functions as a safety net for passengers working late, staying after at school, or delayed for some other reason.

In the example of Route 97, two blocks begin at the western terminal (A) and one begins at the eastern terminal (D). Why don't they all begin at the same place, especially since A is only 10 minutes from the garage while D is 20 minutes away?

Once the decision regarding the time to begin service in both directions is made, the blocking process is intended to place the vehicles where they need to be. In the previous chapter, the decision was made to begin eastbound service at 6:00 AM and westbound service at 6:15 AM. In this simple example, the only way to do this is to pull out Block 9703 to D. In the intermediate and advanced sections below, we will discuss other blocking strategies regarding pull-out, such as beginning a trip mid-route and minimizing deadhead time by pulling out a block into revenue service as soon as possible.

Do the same principles regarding blocking apply in more complex cases where more than one route is involved?

The short answer is yes, as you will see in the intermediate and advanced sections. An expanded blocking exercise would include all trips operated from the same garage. Obviously, as the task gets more complex, the ability to perform blocking by hand becomes more difficult and the use of computer software grows more advisable.

"Tedious" scheduling tasks used to be a bane of schedulers. Computers have relieved us of most of these. Chief among them are by-hand blocking (the writing the numbers in part, not the strategizing) and calculating mileage. Calculating hours is not the most interesting task, but at least you do not have to keep track of every minor deadhead and service pattern and the number of times they are used. This is truly a routine that computers were built for. But when you are starting out, these tasks give you a "feel" for all the elements that go into a schedule. Doing them also gives you a sense of accomplishment and the knowledge that everything on the schedule is accounted for. That said, we encourage you to travel all of these "long paths." What you learn along the way will be invaluable as you progress as a seasoned scheduler.

The specific process or commands for blocking our trips in a computerized system vary between systems. But almost certainly you will have the option to have the system automatically

pull-in miles

The distance the vehicle travels from the route to the garage. Pull-out miles are included in vehicle miles, but not in revenue miles. Collectively, pull-in miles and pull-out miles are also known as pull miles and are components of deadhead miles.

pull-out miles

The distance the vehicle travels from the garage to the route. Pull-in miles are included in vehicle miles, but not in revenue miles. Collectively, pull-in miles and pull-out miles are also known as pull miles and are components of deadhead miles.

vehicle hours

Total hours of travel by a vehicle, including hours in revenue service (including layover time) and deadhead travel.

revenue hours

The number of hours of service available to passengers for transport on the routes. Excludes deadhead hours, but includes layover time. Calculated for each route and for the system as a whole.

vehicle miles

Total miles of travel by a vehicle, including hours in revenue service and deadhead travel.

revenue miles

The number of miles of service available to passengers for transport on the routes. Excludes deadhead miles. Calculated for each route and for the system as a whole.

block summary table

Summary of vehicle statistics, including platform hours and mileage, by block.

block your trips and provide the result, or allow you to work through and manually hook the trips. In the Route 97 example, the result is guaranteed to be the same as we meet any prescribed layover requirements, and the schedule is simple (presenting the system with few or no alternative hooking options).

Calculating Vehicle Statistics

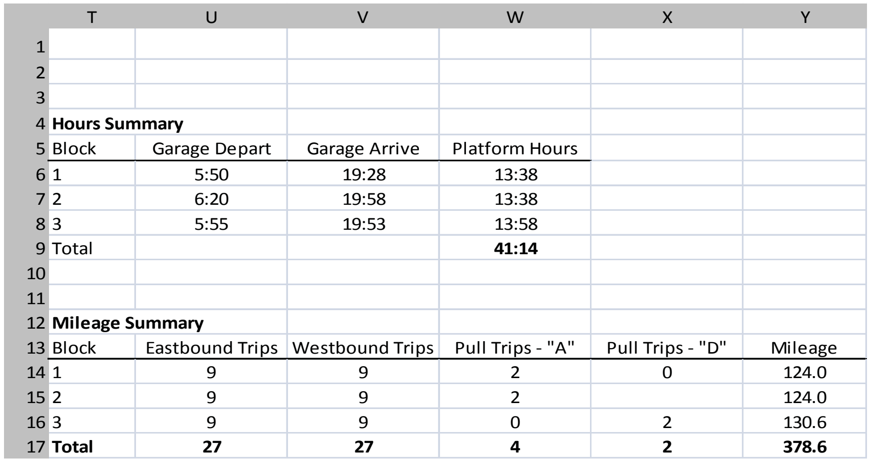
Now that our spreadsheet has been populated with trips and block information we have all the components we need to build summaries of hours, vehicles, and mileage. Typically the key elements needed in a summary table will include:

- **Vehicle Hours:** Comprised of **revenue hours** (including layover time) plus pull-in and pull-out time
- **Vehicle Miles:** Comprised of **revenue miles** plus pull-in and pull-out miles

Depending on the spreadsheet's level of sophistication, these can be calculated automatically, or as fixed formulas. Either way the spreadsheet tools can be used to calculate these numbers.

The method of calculating can be as automated as you require or are capable of developing. The method used in our spreadsheet is to have a set of "fixed" parameters: running times and distances eastbound and westbound, pull out times, and mileage to "A" and "D."

A simple method of estimating mileage would then be to multiply (using a count function) the number of trips by mileage for that direction. The same can be done for hours, or alternatively could be a sum of subtracting the trip arrivals from trip departures. A typical vehicle statistics summary called a **block summary table** may look like the following:



	T	U	V	W	X	Y
1						
2						
3						
4	**Hours Summary**					
5	Block	Garage Depart	Garage Arrive	Platform Hours		
6	1	5:50	19:28	13:38		
7	2	6:20	19:58	13:38		
8	3	5:55	19:53	13:58		
9	Total			**41:14**		
10						
11						
12	**Mileage Summary**					
13	Block	Eastbound Trips	Westbound Trips	Pull Trips - "A"	Pull Trips - "D"	Mileage
14	1	9	9	2	0	124.0
15	2	9	9	2		124.0
16	3	9	9	0	2	130.6
17	**Total**	**27**	**27**	**4**	**2**	**378.6**

For computerized scheduling packages once the blocks have been created, and pulls completed, the costing function will be able to provide the necessary information automatically, according to your agency's requirements.

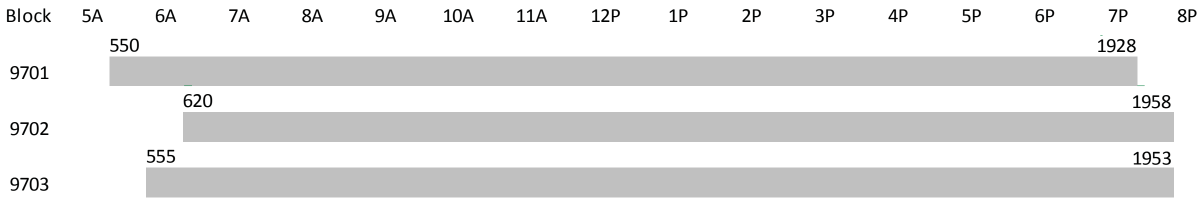
At this point you are able to roughly estimate the number of additional bus operators you will need for this schedule simply by dividing the total platform hours by the average platform time in your runs. This example yields 41:14 hours, which would produce five runs of slightly over 8:15 in duration each. That is a good figure to use for estimates, even though the actual runcut will probably produce somewhat different individual results.

The most practical aspect of this finished schedule is that you now have detailed statistics with which to develop costs for implementing this service. Your finance group should have figures on system costs on a per-hour and per-mile basis which can be applied against the figures in your Hours and Miles table. If your schedule has met the budget goal, you know it positively at this point. If not, you can take steps to reduce the service by cutting back trips, taking a bus out of the cycle, or shortening the route—all actions discussed in the intermediate and advanced sections of Chapter 3 (Schedule Building). These costs are still an estimate at this point; until you cut the runs (see Chapter 5), you will not have pay hours for operators.

Graphing the Blocks

Blocks are often displayed graphically to illustrate the time spans that the blocks are in service. Time spans (in this case, platform time) can be obtained from the vehicle statistics.

An example of a graphic display of Route 97 is shown below. This type of graphic display is especially valuable as a tool for runcutting in the absence of a computerized scheduling software package. Computerized packages can generate these graphs automatically.



Tip Use your blocks to estimate your operator needs.

$$\frac{\text{Total platform time}}{\text{Average platform time}} = \text{\# operators needed}$$

This is only a rough estimate, but it will be a useful check on the runcut.

block graph

A graphical representation of all blocks assigned to a garage that must be considered in the runcut solution. The graph includes, at a minimum, the start and end times of each block, and may also include terminal times and all eligible relief times. Understanding the number and duration of all blocks is an important requisite in reaching an optimal runcut solution.

LEVEL
1

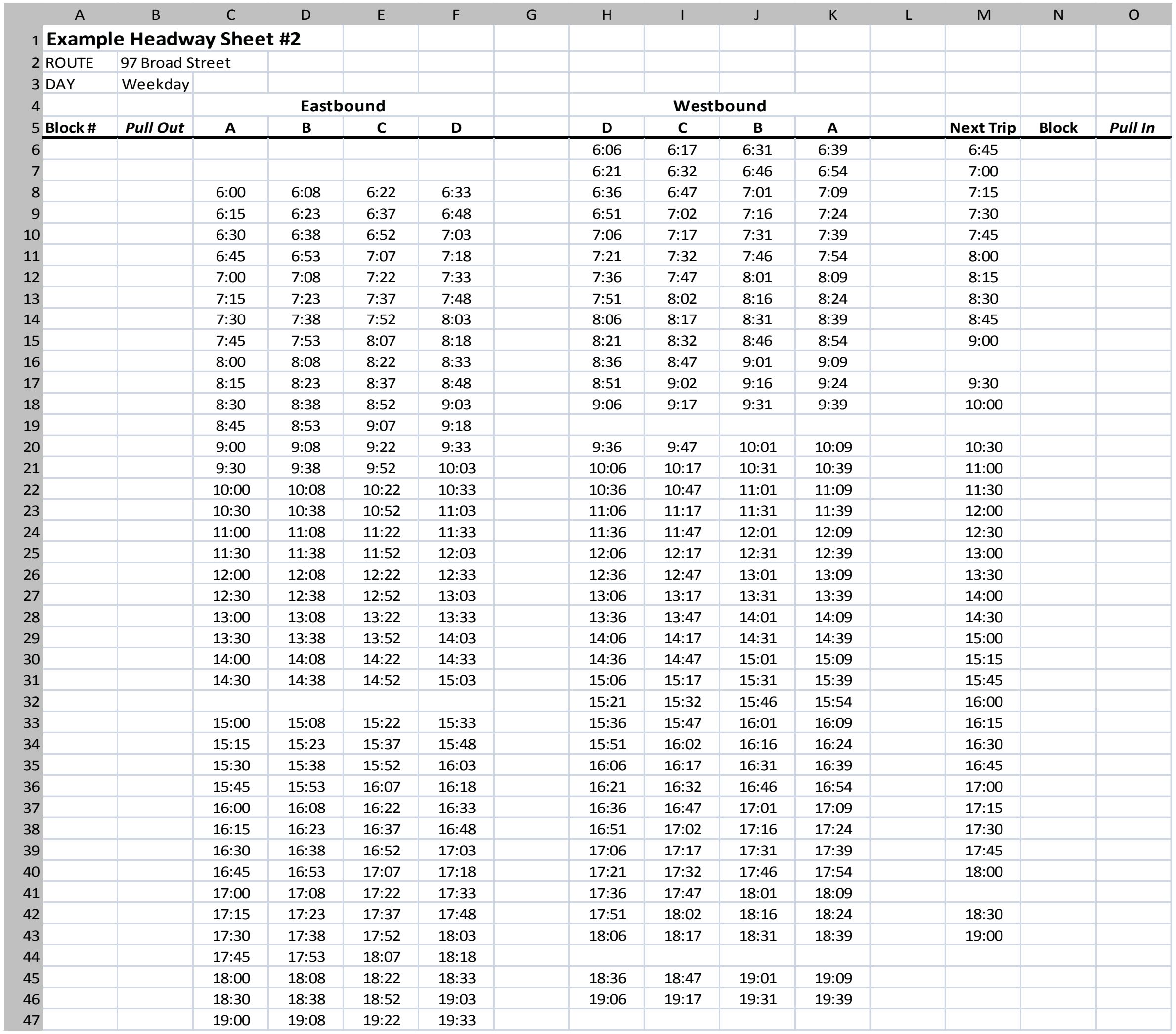
End of Basic Blocking.
The Intermediate Section of Blocking continues on the next page.

To jump to Runcutting, go to page 5-1.

4.2 Intermediate Blocking—Blocking a Slightly More Intricate Route 97 Schedule

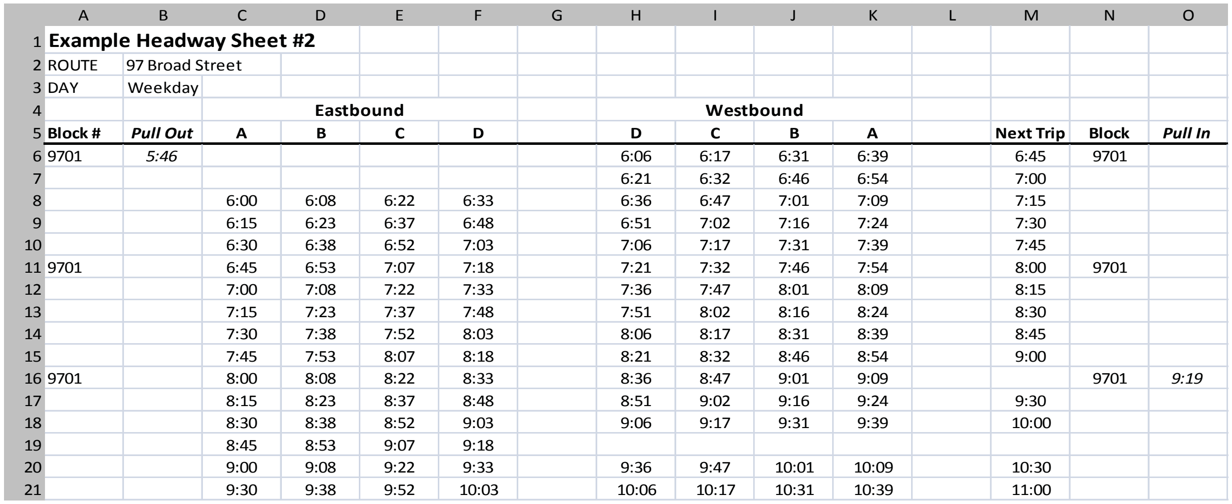
LEVEL
2A

The previous section of the Schedule Building chapter introduced the first intricacy in the simple Route 97 schedule: providing more frequent service (every 15 minutes) during peak morning and afternoon periods. With a round-trip running time of 66 minutes, we concluded that a cycle time of 75 minutes would be optimal. As the new schedule was developed, trips were moved and layover time changed at terminals to make departure times consistent throughout the day. The final Route 97 schedule is shown below.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**Example Headway Sheet #2**														
2	ROUTE	97 Broad Street													
3	DAY	Weekday													
4			**Eastbound**					**Westbound**							
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	**Block**	***Pull In***
6								6:06	6:17	6:31	6:39		6:45		
7								6:21	6:32	6:46	6:54		7:00		
8			6:00	6:08	6:22	6:33		6:36	6:47	7:01	7:09		7:15		
9			6:15	6:23	6:37	6:48		6:51	7:02	7:16	7:24		7:30		
10			6:30	6:38	6:52	7:03		7:06	7:17	7:31	7:39		7:45		
11			6:45	6:53	7:07	7:18		7:21	7:32	7:46	7:54		8:00		
12			7:00	7:08	7:22	7:33		7:36	7:47	8:01	8:09		8:15		
13			7:15	7:23	7:37	7:48		7:51	8:02	8:16	8:24		8:30		
14			7:30	7:38	7:52	8:03		8:06	8:17	8:31	8:39		8:45		
15			7:45	7:53	8:07	8:18		8:21	8:32	8:46	8:54		9:00		
16			8:00	8:08	8:22	8:33		8:36	8:47	9:01	9:09				
17			8:15	8:23	8:37	8:48		8:51	9:02	9:16	9:24		9:30		
18			8:30	8:38	8:52	9:03		9:06	9:17	9:31	9:39		10:00		
19			8:45	8:53	9:07	9:18									
20			9:00	9:08	9:22	9:33		9:36	9:47	10:01	10:09		10:30		
21			9:30	9:38	9:52	10:03		10:06	10:17	10:31	10:39		11:00		
22			10:00	10:08	10:22	10:33		10:36	10:47	11:01	11:09		11:30		
23			10:30	10:38	10:52	11:03		11:06	11:17	11:31	11:39		12:00		
24			11:00	11:08	11:22	11:33		11:36	11:47	12:01	12:09		12:30		
25			11:30	11:38	11:52	12:03		12:06	12:17	12:31	12:39		13:00		
26			12:00	12:08	12:22	12:33		12:36	12:47	13:01	13:09		13:30		
27			12:30	12:38	12:52	13:03		13:06	13:17	13:31	13:39		14:00		
28			13:00	13:08	13:22	13:33		13:36	13:47	14:01	14:09		14:30		
29			13:30	13:38	13:52	14:03		14:06	14:17	14:31	14:39		15:00		
30			14:00	14:08	14:22	14:33		14:36	14:47	15:01	15:09		15:15		
31			14:30	14:38	14:52	15:03		15:06	15:17	15:31	15:39		15:45		
32								15:21	15:32	15:46	15:54		16:00		
33			15:00	15:08	15:22	15:33		15:36	15:47	16:01	16:09		16:15		
34			15:15	15:23	15:37	15:48		15:51	16:02	16:16	16:24		16:30		
35			15:30	15:38	15:52	16:03		16:06	16:17	16:31	16:39		16:45		
36			15:45	15:53	16:07	16:18		16:21	16:32	16:46	16:54		17:00		
37			16:00	16:08	16:22	16:33		16:36	16:47	17:01	17:09		17:15		
38			16:15	16:23	16:37	16:48		16:51	17:02	17:16	17:24		17:30		
39			16:30	16:38	16:52	17:03		17:06	17:17	17:31	17:39		17:45		
40			16:45	16:53	17:07	17:18		17:21	17:32	17:46	17:54		18:00		
41			17:00	17:08	17:22	17:33		17:36	17:47	18:01	18:09				
42			17:15	17:23	17:37	17:48		17:51	18:02	18:16	18:24		18:30		
43			17:30	17:38	17:52	18:03		18:06	18:17	18:31	18:39		19:00		
44			17:45	17:53	18:07	18:18									
45			18:00	18:08	18:22	18:33		18:36	18:47	19:01	19:09				
46			18:30	18:38	18:52	19:03		19:06	19:17	19:31	19:39				
47			19:00	19:08	19:22	19:33									

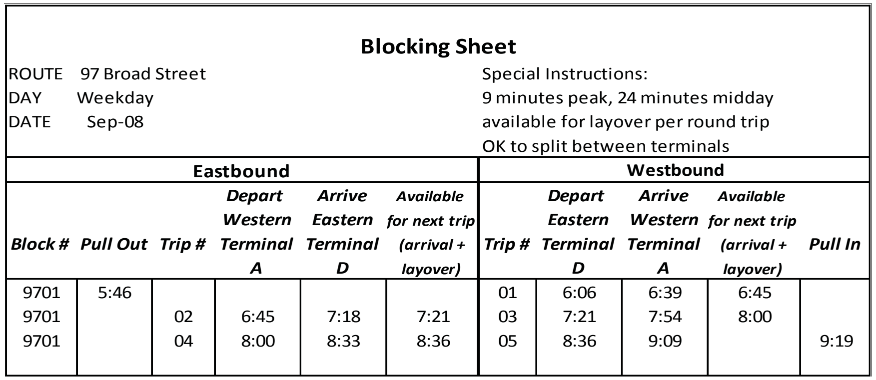
In numbering the blocks, we will follow the convention noted in the basic section of keeping the block numbers in order. So, the first trip (westbound at 6:06) will be assigned to block 9701. Enter the block number for this trip, and for all subsequent trips hooked to this trip.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**Example Headway Sheet #2**														
2	ROUTE	97 Broad Street													
3	DAY	Weekday													
4			Eastbound					Westbound							
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	**Block**	***Pull In***
6	9701	*5:46*						6:06	6:17	6:31	6:39		6:45	9701	
7								6:21	6:32	6:46	6:54		7:00		
8			6:00	6:08	6:22	6:33		6:36	6:47	7:01	7:09		7:15		
9			6:15	6:23	6:37	6:48		6:51	7:02	7:16	7:24		7:30		
10			6:30	6:38	6:52	7:03		7:06	7:17	7:31	7:39		7:45		
11	9701		6:45	6:53	7:07	7:18		7:21	7:32	7:46	7:54		8:00	9701	
12			7:00	7:08	7:22	7:33		7:36	7:47	8:01	8:09		8:15		
13			7:15	7:23	7:37	7:48		7:51	8:02	8:16	8:24		8:30		
14			7:30	7:38	7:52	8:03		8:06	8:17	8:31	8:39		8:45		
15			7:45	7:53	8:07	8:18		8:21	8:32	8:46	8:54		9:00		
16	9701		8:00	8:08	8:22	8:33		8:36	8:47	9:01	9:09			9701	*9:19*
17			8:15	8:23	8:37	8:48		8:51	9:02	9:16	9:24		9:30		
18			8:30	8:38	8:52	9:03		9:06	9:17	9:31	9:39		10:00		
19			8:45	8:53	9:07	9:18									
20			9:00	9:08	9:22	9:33		9:36	9:47	10:01	10:09		10:30		
21			9:30	9:38	9:52	10:03		10:06	10:17	10:31	10:39		11:00		

When the Block 9701 trip arrives at A at 9:09, the first decision arises: should we pull the block in or should we assign it to make the 9:30 trip? For now, we will go with the least expensive alternative, which is to minimize layover time (within limits, of course) by hooking the 9:24 arrival to the 9:30 trip and pulling in the 9:09 trip. We might change our minds later if the swap would result in a block that would provide a better runcut. Note that this is a decision that never had to be made in the simple schedule, where headways and running times remained consistent throughout the day.

The revised schedule also needs a new blocking sheet. Entries for block 9701 are shown below.



Blocking Sheet

ROUTE 97 Broad Street
DAY Weekday
DATE Sep-08

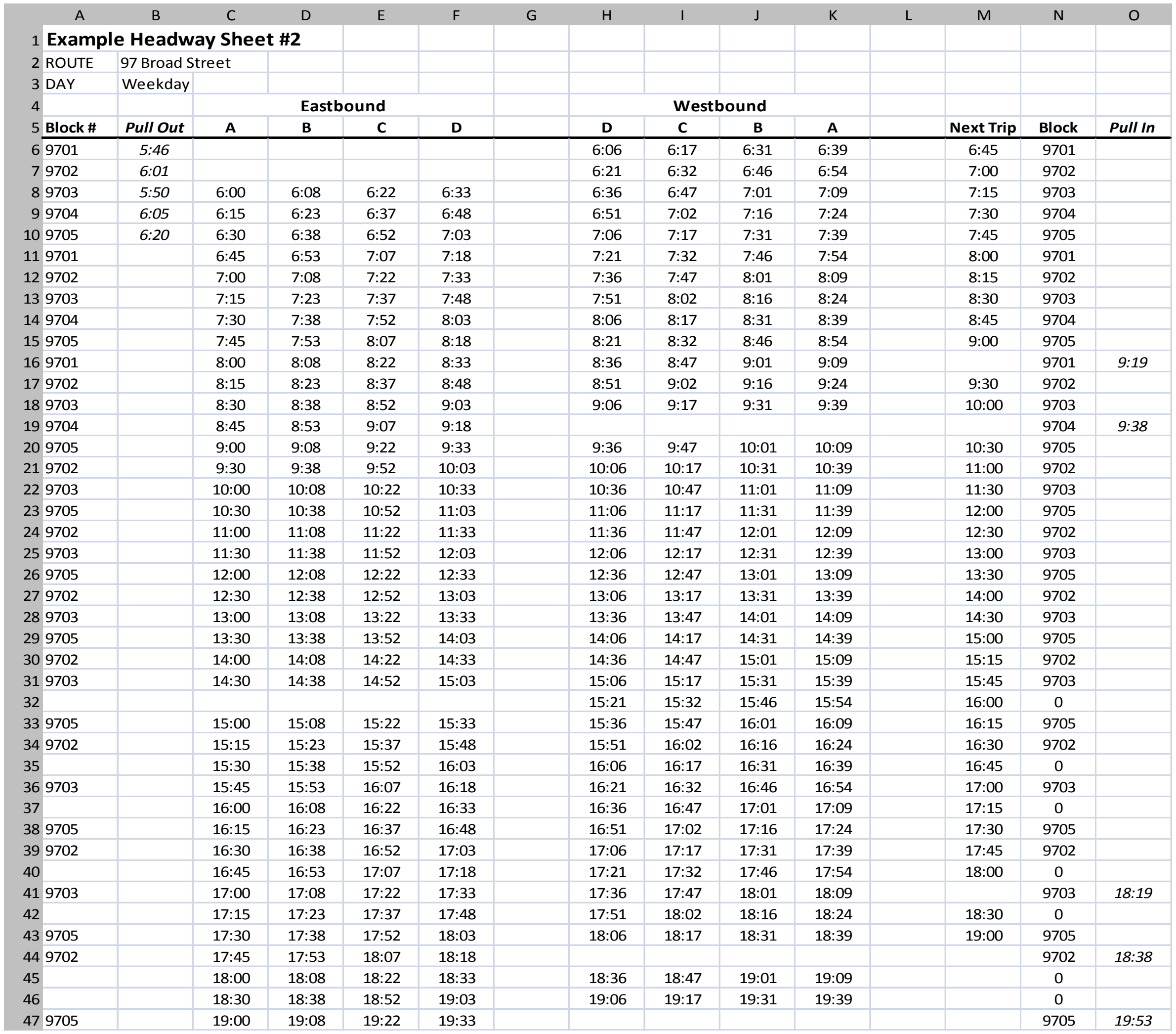
Special Instructions:
9 minutes peak, 24 minutes midday
available for layover per round trip
OK to split between terminals

Eastbound						**Westbound**				
Block #	***Pull Out***	***Trip #***	***Depart Western Terminal A***	***Arrive Eastern Terminal D***	***Available for next trip (arrival + layover)***	***Trip #***	***Depart Eastern Terminal D***	***Arrive Western Terminal A***	***Available for next trip (arrival + layover)***	***Pull In***
9701	5:46					01	6:06	6:39	6:45	
9701		02	6:45	7:18	7:21	03	7:21	7:54	8:00	
9701		04	8:00	8:33	8:36	05	8:36	9:09		9:19

Tip When blocking a schedule where headways change throughout the day, there will be cases in which two blocks are available to make the next trip. The scheduler should choose the block with the least amount of layover time, assuming that minimum layover requirements are met. Exceptions to this rule are discussed in Chapter 5: Runcutting.

Continue the blocking process in the morning. As seen below, three blocks (9702, 9703, and 9705) are **base blocks** that operate throughout the day, while the two other blocks pull in near 9:00 AM, the end of the morning peak period. As expected, the schedule has two extra buses in the morning peak period that were not there in the original schedule.

The same thought process should be used for hooking the PM peak blocks. When the layover increases to a considerable amount and there is a later trip that can hook, pull in the earlier trip. This is the case with the trip arriving at A at 18:09. Pull in this block and hook the trip arriving at 18:24 with the next trip at 18:30.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**Example Headway Sheet #2**														
2	ROUTE	97 Broad Street													
3	DAY	Weekday													
4			**Eastbound**					**Westbound**							
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	**Block**	***Pull In***
6	9701	*5:46*						6:06	6:17	6:31	6:39		6:45	9701	
7	9702	*6:01*						6:21	6:32	6:46	6:54		7:00	9702	
8	9703	*5:50*	6:00	6:08	6:22	6:33		6:36	6:47	7:01	7:09		7:15	9703	
9	9704	*6:05*	6:15	6:23	6:37	6:48		6:51	7:02	7:16	7:24		7:30	9704	
10	9705	*6:20*	6:30	6:38	6:52	7:03		7:06	7:17	7:31	7:39		7:45	9705	
11	9701		6:45	6:53	7:07	7:18		7:21	7:32	7:46	7:54		8:00	9701	
12	9702		7:00	7:08	7:22	7:33		7:36	7:47	8:01	8:09		8:15	9702	
13	9703		7:15	7:23	7:37	7:48		7:51	8:02	8:16	8:24		8:30	9703	
14	9704		7:30	7:38	7:52	8:03		8:06	8:17	8:31	8:39		8:45	9704	
15	9705		7:45	7:53	8:07	8:18		8:21	8:32	8:46	8:54		9:00	9705	
16	9701		8:00	8:08	8:22	8:33		8:36	8:47	9:01	9:09			9701	*9:19*
17	9702		8:15	8:23	8:37	8:48		8:51	9:02	9:16	9:24		9:30	9702	
18	9703		8:30	8:38	8:52	9:03		9:06	9:17	9:31	9:39		10:00	9703	
19	9704		8:45	8:53	9:07	9:18								9704	*9:38*
20	9705		9:00	9:08	9:22	9:33		9:36	9:47	10:01	10:09		10:30	9705	
21	9702		9:30	9:38	9:52	10:03		10:06	10:17	10:31	10:39		11:00	9702	
22	9703		10:00	10:08	10:22	10:33		10:36	10:47	11:01	11:09		11:30	9703	
23	9705		10:30	10:38	10:52	11:03		11:06	11:17	11:31	11:39		12:00	9705	
24	9702		11:00	11:08	11:22	11:33		11:36	11:47	12:01	12:09		12:30	9702	
25	9703		11:30	11:38	11:52	12:03		12:06	12:17	12:31	12:39		13:00	9703	
26	9705		12:00	12:08	12:22	12:33		12:36	12:47	13:01	13:09		13:30	9705	
27	9702		12:30	12:38	12:52	13:03		13:06	13:17	13:31	13:39		14:00	9702	
28	9703		13:00	13:08	13:22	13:33		13:36	13:47	14:01	14:09		14:30	9703	
29	9705		13:30	13:38	13:52	14:03		14:06	14:17	14:31	14:39		15:00	9705	
30	9702		14:00	14:08	14:22	14:33		14:36	14:47	15:01	15:09		15:15	9702	
31	9703		14:30	14:38	14:52	15:03		15:06	15:17	15:31	15:39		15:45	9703	
32								15:21	15:32	15:46	15:54		16:00	0	
33	9705		15:00	15:08	15:22	15:33		15:36	15:47	16:01	16:09		16:15	9705	
34	9702		15:15	15:23	15:37	15:48		15:51	16:02	16:16	16:24		16:30	9702	
35			15:30	15:38	15:52	16:03		16:06	16:17	16:31	16:39		16:45	0	
36	9703		15:45	15:53	16:07	16:18		16:21	16:32	16:46	16:54		17:00	9703	
37			16:00	16:08	16:22	16:33		16:36	16:47	17:01	17:09		17:15	0	
38	9705		16:15	16:23	16:37	16:48		16:51	17:02	17:16	17:24		17:30	9705	
39	9702		16:30	16:38	16:52	17:03		17:06	17:17	17:31	17:39		17:45	9702	
40			16:45	16:53	17:07	17:18		17:21	17:32	17:46	17:54		18:00	0	
41	9703		17:00	17:08	17:22	17:33		17:36	17:47	18:01	18:09			9703	*18:19*
42			17:15	17:23	17:37	17:48		17:51	18:02	18:16	18:24		18:30	0	
43	9705		17:30	17:38	17:52	18:03		18:06	18:17	18:31	18:39		19:00	9705	
44	9702		17:45	17:53	18:07	18:18								9702	*18:38*
45			18:00	18:08	18:22	18:33		18:36	18:47	19:01	19:09			0	
46			18:30	18:38	18:52	19:03		19:06	19:17	19:31	19:39			0	
47	9705		19:00	19:08	19:22	19:33								9705	*19:53*

base block

A block that is in service during the AM peak, midday, the PM peak and possibly the evening.

AM Block

A block that is in service only during the AM peak period.

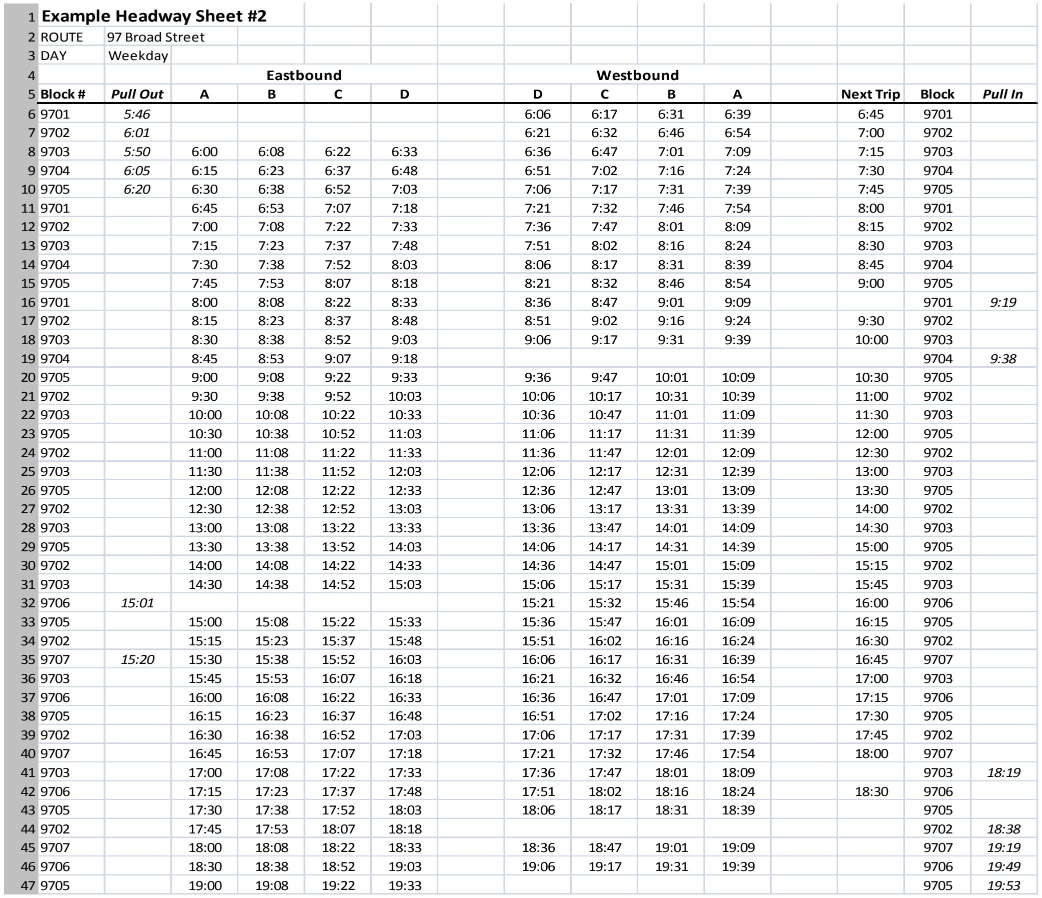
PM block

A block that is in service only during the PM peak period.

The blocking exercise is not quite complete: as you can see, several afternoon peak trips do not have a block assigned. As the headway changes from 30 to 15 minutes, the two added blocks used in the morning are needed again.

These two peak blocks can be numbered as the same (4 and 5), or in the PM may have new numbers (6 and 7). That will often depend on agency naming requirements and data system needs.

In this example, a different block number is used for each pull-out. There are lots of block numbering schemes in use at different transit properties around the country, but this one is used here to keep this example as straightforward as possible. Add in these two new blocks, 9706 and 9707. The final headway sheet with the blocks entered is shown below.



1	**Example Headway Sheet #2**														
2	ROUTE	97 Broad Street													
3	DAY	Weekday													
4			**Eastbound**					**Westbound**							
5	**Block #**	***Pull Out***	**A**	**B**	**C**	**D**		**D**	**C**	**B**	**A**		**Next Trip**	**Block**	***Pull In***
6	9701	*5:46*						6:06	6:17	6:31	6:39		6:45	9701	
7	9702	*6:01*						6:21	6:32	6:46	6:54		7:00	9702	
8	9703	*5:50*	6:00	6:08	6:22	6:33		6:36	6:47	7:01	7:09		7:15	9703	
9	9704	*6:05*	6:15	6:23	6:37	6:48		6:51	7:02	7:16	7:24		7:30	9704	
10	9705	*6:20*	6:30	6:38	6:52	7:03		7:06	7:17	7:31	7:39		7:45	9705	
11	9701		6:45	6:53	7:07	7:18		7:21	7:32	7:46	7:54		8:00	9701	
12	9702		7:00	7:08	7:22	7:33		7:36	7:47	8:01	8:09		8:15	9702	
13	9703		7:15	7:23	7:37	7:48		7:51	8:02	8:16	8:24		8:30	9703	
14	9704		7:30	7:38	7:52	8:03		8:06	8:17	8:31	8:39		8:45	9704	
15	9705		7:45	7:53	8:07	8:18		8:21	8:32	8:46	8:54		9:00	9705	
16	9701		8:00	8:08	8:22	8:33		8:36	8:47	9:01	9:09			9701	*9:19*
17	9702		8:15	8:23	8:37	8:48		8:51	9:02	9:16	9:24		9:30	9702	
18	9703		8:30	8:38	8:52	9:03		9:06	9:17	9:31	9:39		10:00	9703	
19	9704		8:45	8:53	9:07	9:18								9704	*9:38*
20	9705		9:00	9:08	9:22	9:33		9:36	9:47	10:01	10:09		10:30	9705	
21	9702		9:30	9:38	9:52	10:03		10:06	10:17	10:31	10:39		11:00	9702	
22	9703		10:00	10:08	10:22	10:33		10:36	10:47	11:01	11:09		11:30	9703	
23	9705		10:30	10:38	10:52	11:03		11:06	11:17	11:31	11:39		12:00	9705	
24	9702		11:00	11:08	11:22	11:33		11:36	11:47	12:01	12:09		12:30	9702	
25	9703		11:30	11:38	11:52	12:03		12:06	12:17	12:31	12:39		13:00	9703	
26	9705		12:00	12:08	12:22	12:33		12:36	12:47	13:01	13:09		13:30	9705	
27	9702		12:30	12:38	12:52	13:03		13:06	13:17	13:31	13:39		14:00	9702	
28	9703		13:00	13:08	13:22	13:33		13:36	13:47	14:01	14:09		14:30	9703	
29	9705		13:30	13:38	13:52	14:03		14:06	14:17	14:31	14:39		15:00	9705	
30	9702		14:00	14:08	14:22	14:33		14:36	14:47	15:01	15:09		15:15	9702	
31	9703		14:30	14:38	14:52	15:03		15:06	15:17	15:31	15:39		15:45	9703	
32	9706	*15:01*						15:21	15:32	15:46	15:54		16:00	9706	
33	9705		15:00	15:08	15:22	15:33		15:36	15:47	16:01	16:09		16:15	9705	
34	9702		15:15	15:23	15:37	15:48		15:51	16:02	16:16	16:24		16:30	9702	
35	9707	*15:20*	15:30	15:38	15:52	16:03		16:06	16:17	16:31	16:39		16:45	9707	
36	9703		15:45	15:53	16:07	16:18		16:21	16:32	16:46	16:54		17:00	9703	
37	9706		16:00	16:08	16:22	16:33		16:36	16:47	17:01	17:09		17:15	9706	
38	9705		16:15	16:23	16:37	16:48		16:51	17:02	17:16	17:24		17:30	9705	
39	9702		16:30	16:38	16:52	17:03		17:06	17:17	17:31	17:39		17:45	9702	
40	9707		16:45	16:53	17:07	17:18		17:21	17:32	17:46	17:54		18:00	9707	
41	9703		17:00	17:08	17:22	17:33		17:36	17:47	18:01	18:09			9703	*18:19*
42	9706		17:15	17:23	17:37	17:48		17:51	18:02	18:16	18:24		18:30	9706	
43	9705		17:30	17:38	17:52	18:03		18:06	18:17	18:31	18:39			9705	
44	9702		17:45	17:53	18:07	18:18								9702	*18:38*
45	9707		18:00	18:08	18:22	18:33		18:36	18:47	19:01	19:09			9707	*19:19*
46	9706		18:30	18:38	18:52	19:03		19:06	19:17	19:31	19:39			9706	*19:49*
47	9705		19:00	19:08	19:22	19:33								9705	*19:53*

The final blocking sheet for Route 97 is shown below.

Blocking Sheet

ROUTE 97 Broad Street
DAY Weekday
DATE Sep-08

Special Instructions:
9 minutes peak, 24 minutes midday
available for layover per round trip
OK to split between terminals

		Eastbound				**Westbound**				
Block #	***Pull Out***	***Trip #***	***Depart Western Terminal A***	***Arrive Eastern Terminal D***	***Available for next trip (arrival + layover)***	***Trip #***	***Depart Eastern Terminal D***	***Arrive Western Terminal A***	***Available for next trip (arrival + layover)***	***Pull In***
9701	5:46					01	6:06	6:39	6:45	
9701		02	6:45	7:18	7:21	03	7:21	7:54	8:00	
9701		04	8:00	8:33	8:36	05	8:36	9:09		9:19
9702	6:01					01	6:21	6:54	7:00	
9702		02	7:00	7:33	7:36	03	7:36	8:09	8:15	
9702		04	8:15	8:48	8:51	05	8:51	9:24	9:30	
9702		06	9:30	10:03	10:06	07	10:06	10:39	11:00	
9702		08	11:00	11:33	11:36	09	11:36	12:09	12:30	
9702		10	12:30	13:03	13:06	11	13:06	13:39	14:00	
9702		12	14:00	14:33	14:36	13	14:36	15:09	15:15	
9702		14	15:15	15:48	15:51	15	15:51	16:24	16:30	
9702		16	16:30	17:03	17:06	17	17:06	17:39	17:45	
9702		18	17:45	18:18						18:38
9703	5:50	01	6:00	6:33	6:36	02	6:36	7:09	7:15	
9703		03	7:15	7:48	7:51	04	7:51	8:24	8:30	
9703		05	8:30	9:03	9:06	06	9:06	9:39	10:00	
9703		07	10:00	10:33	10:36	08	10:36	11:09	11:30	
9703		09	11:30	12:03	12:06	10	12:06	12:39	13:00	
9703		11	13:00	13:33	13:36	12	13:36	14:09	14:30	
9703		13	14:30	15:03	15:06	14	15:06	15:39	15:45	
9703		15	15:45	16:18	16:21	16	16:21	16:54	17:00	
9703		17	17:00	17:33	17:36	18	17:36	18:09		18:19
9704	6:05	01	6:15	6:48	6:51	02	6:51	7:24	7:30	
9704		03	7:30	8:03	8:06	04	8:06	8:39	8:45	
9704		05	8:45	9:18						9:38
9705	6:20	01	6:30	7:03	7:06	02	7:06	7:39	7:45	
9705		03	7:45	8:18	8:21	04	8:21	8:54	9:00	
9705		05	9:00	9:33	9:36	06	9:36	10:09	10:30	
9705		07	10:30	11:03	11:06	08	11:06	11:39	12:00	
9705		09	12:00	12:33	12:36	10	12:36	13:09	13:30	
9705		11	13:30	14:03	14:06	12	14:06	14:39	15:00	
9705		13	15:00	15:33	15:36	14	15:36	16:09	16:15	
9705		15	16:15	16:48	16:51	16	16:51	17:24	17:30	
9705		17	17:30	18:03	18:06	18	18:06	18:39	19:00	
9705		19	19:00	19:33						19:53
9706	15:01					01	15:21	15:54	16:00	
9706		02	16:00	16:33	16:36	03	16:36	17:09	17:15	
9706		04	17:15	17:48	17:51	05	17:51	18:24	18:30	
9706		06	18:30	19:03	19:06	07	19:06	19:39		19:49
9707	15:20	01	15:30	16:03	16:06	02	16:06	16:39	16:45	
9707		03	16:45	17:18	17:21	04	17:21	17:54	18:00	
9707		05	18:00	18:33	18:36	06	18:36	19:09		19:19

With a computerized scheduling software package, the blocking could be undertaken automatically or hooked trip by trip. As with our simple blocking exercise, the use of a computerized scheduling package will make the blocking process easy and less prone to error. If we decided to allow some additional layover after the AM Peak, for example, by assigning the 9:09 arrival at A on Block 9701 to the 9:30 departure, this would almost certainly require hand intervention. The package will look to minimize hours in all cases (unless rules are created to force it to do otherwise), and thus the 9:09 trip will pull in and the 9:24 will make the 9:30 departure. The scheduling software package will have saved 15 minutes and therefore have done what has been asked of it.

Now that your blocking strategy is more complicated, you should proof your sheet by counting the respective pull-outs and pull-ins to make sure that all are accounted for—every bus that goes out needs to come back! In this example, there are seven pull-outs and seven pull-ins, and each trip has an associated block number.

With seven pull-outs, the novice scheduler might conclude that this schedule requires seven buses. Not true! The number of pull-outs does not always equal the number of buses required. In this example, the same vehicle can be used for block 9701 and 9706 and the same vehicle can be used for block 9704 and 9707. The potential for confusion is one reason why some agencies choose to keep the same block number for peak-only blocks in the AM and PM. As a rule, however, computerized scheduling packages will not repeat a block number during the operating day unless programmed to do so.

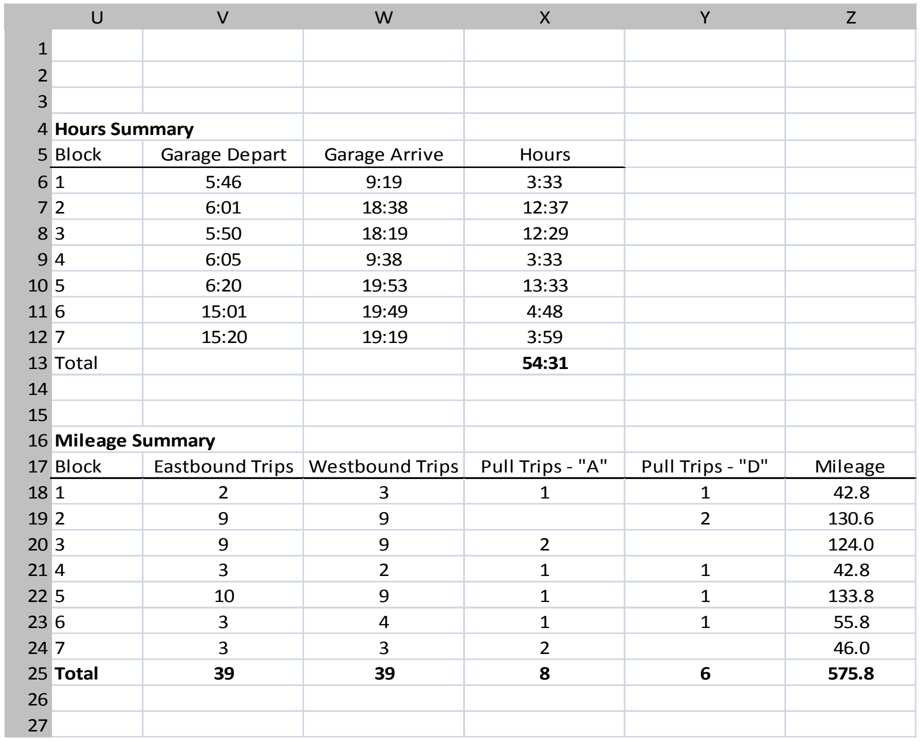
Is there a sure way of confirming how many buses you need? Add the number of all-day blocks plus the number of AM only blocks to calculate the number of buses needed in the AM peak. Then add the number of all-day blocks plus the number of PM only blocks for the number of buses needed in the PM peak. Route 97 has three all-day blocks, two AM blocks, and two PM blocks, so you need five buses for the AM peak and five buses for the PM peak.

Some routes may need more buses in the AM peak, because demand can be more highly concentrated in the morning—everyone needs to get to work at the same time, but not everyone goes straight home from work in the afternoon, and school bell times in the morning coincide with the AM peak. Other routes may need more buses in the PM peak because running times are longer due to afternoon traffic congestion. It is always a good idea to calculate the vehicles needed in both peak periods.

Once the blocking is complete, you will need to revisit the Vehicle Hours & Mileage Summary table and the mileage calculation—here we assume this table needs manual input for some cells. Add the new blocks to the table along with their out and in times. Also replace the out and in times for the original blocks 9701 through 9703, as they have changed. Following the convention noted above, we numbered the two new AM peak blocks 9704 and 9705 and continued this series for the PM blocks, creating blocks 9706 and 9707. The revised summary table is shown on page 4-24.

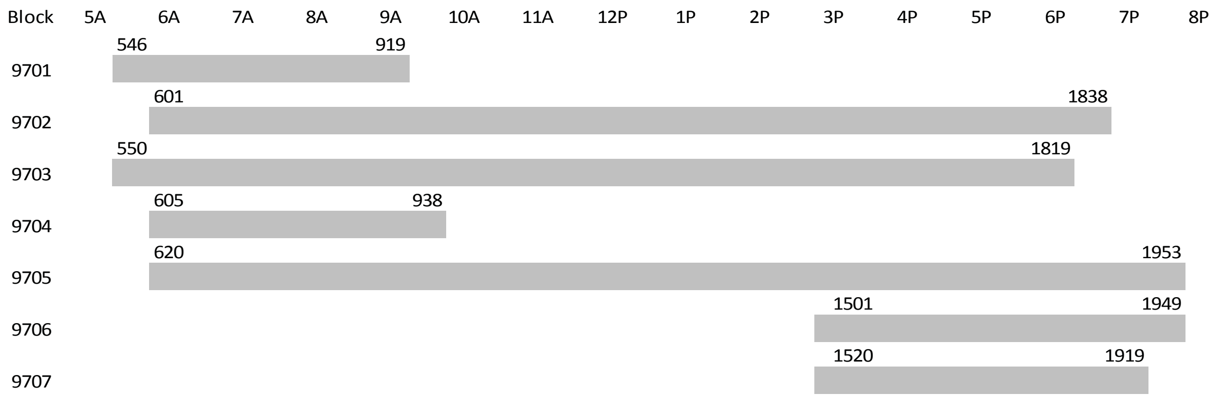
Make sure you revise the totals for the schedule. Comparing this with the 30-minute service schedule, we have added 13:17 (41:14 versus 54:31). Our estimate was for an additional 14 hours, so we have finished very close to that estimate. The approximate result is one additional operator run and ¾ of a run, which probably will get combined with other work to become another operator requirement.

The mileage matrix needs to be updated as the number of trips in each direction for each block has changed almost completely. So have most of the pull-out and pull-in directions. Depending on how your formulas are set up, this may simply be a matter of updating the “total trips” cell (which should then be automatically multiplied by the distance). Alternatively, if your sheet has a “count” function to count trips in each direction the mileage will have updated automatically. The revised mileage totals 575.8, an increase of 197.2 over the 378.6 of the original schedule. That is a somewhat over 50% increase in mileage for a doubling of peak hour service—pretty typical of what you would expect for this type of change.



	U	V	W	X	Y	Z
1						
2						
3						
4	**Hours Summary**					
5	Block	Garage Depart	Garage Arrive	Hours		
6	1	5:46	9:19	3:33		
7	2	6:01	18:38	12:37		
8	3	5:50	18:19	12:29		
9	4	6:05	9:38	3:33		
10	5	6:20	19:53	13:33		
11	6	15:01	19:49	4:48		
12	7	15:20	19:19	3:59		
13	Total			**54:31**		
14						
15						
16	**Mileage Summary**					
17	Block	Eastbound Trips	Westbound Trips	Pull Trips - "A"	Pull Trips - "D"	Mileage
18	1	2	3	1	1	42.8
19	2	9	9		2	130.6
20	3	9	9	2		124.0
21	4	3	2	1	1	42.8
22	5	10	9	1	1	133.8
23	6	3	4	1	1	55.8
24	7	3	3	2		46.0
25	**Total**	**39**	**39**	**8**	**6**	**575.8**
26						
27						

Computerized packages will have automatically regenerated the statistics and reassigned block numbers (assuming you choose to) as soon as the schedule had been revised. Computerized packages can also generate the block graph shown below.



LEVEL 2A

End of Intermediate Blocking, Part A

Intermediate Blocking, Part B continues on the next page.

To jump to Runcutting, go to page 5-1.

4.3 Blocking a More Complex Schedule

LEVEL 2B

In many transit systems, routes are not designed to operate with the same headway and running times throughout the day. Most urban routes are designed with complexities that include multiple terminals for route branches, variable running times, headway variations, added trips related to school bell times, mid-route layover at a timed transfer location, and route interlining. Route 96-Pasco Avenue will be blocked in this section.

The skills involved in blocking a more complex route are the same as the basic skills that have already been discussed for a simple route. Trips are hooked or linked together into vehicle assignments based on the requirements for layover time and the goal of minimizing hours and vehicles. This is a good point to summarize some basic rules for blocking a complex route.

- **It is not necessary to provide equal layover time at both ends of the route.** The target layover time is usually based on the round-trip running time. Generally it is a good idea to provide some layover time at each end of the route, since delays can occur in either direction. It is not necessary, however, especially in cases where there is mid-route layover time at a timed transfer location. In the previous Route 97 example, we provided layover time at both ends of the route, but during the midday the layover was three minutes at one end and 21 minutes at the other. So, a corollary to this rule is that layover time does not have to be evenly distributed at both ends of the route.
- **Some blocks are likely to operate only during peak periods, while other blocks will operate throughout the day.** The Route 97 example above featured three all-day blocks, two AM blocks, and two PM blocks. When initially linking trips into blocks, trips are hooked until there is either too little layover time to comply with labor contract requirements or too much layover time compared to another hooking possibility. Some peak blocks may make only a single trip to augment peak-of-the-peak service or to add service during school peaks. Although such blocks may serve an important need, single-trip blocks are costly, especially when they require a dedicated peak vehicle. Interlining with another block is almost always desirable.
- **Tracking trip assignments to blocks on the master schedule, as we did with Route 97, reduces the chance of error.** One of the more common mistakes involves the scheduler inadvertently missing single trips in the blocking thread. If not caught in time, this requires extensive reworking. Computerized scheduling software packages track trips and blocks automatically.

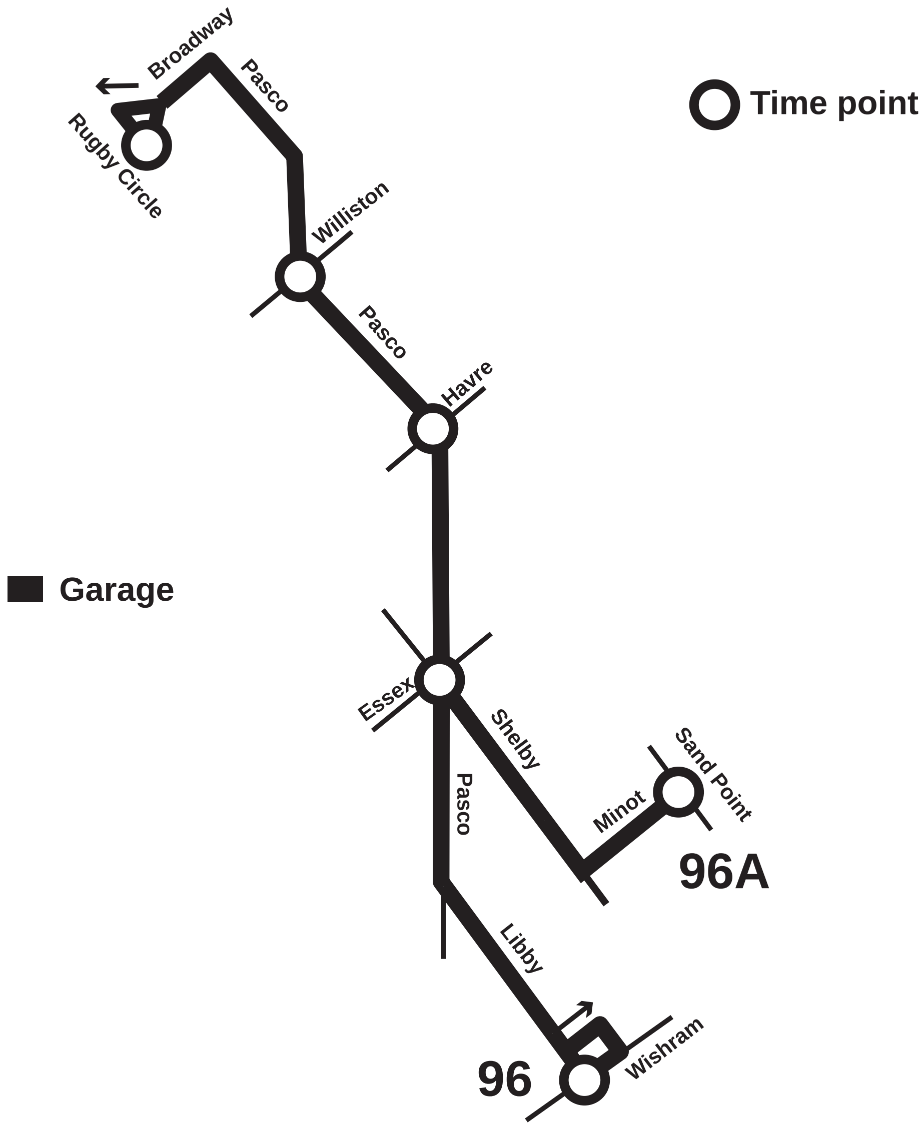
match-up sheet

A listing of all arrival and leave times of all routes at a particular terminal. This sheet simplifies the process of interlining trips.

- **Route variations are generally interlined only at common terminals.** For example, departing Route 96 trips in this section's example from the common terminal at Rugby Circle may serve either branch. Trips that arrive at either of the "outer" or south terminals (Sand Point or Libby & Wishram) would leave from that terminal in revenue service, rather than deadheading from one terminal to the other.
- **All trips do not have to start and end at one end of the route.** Pull-out trips may start at a midpoint of the route close to the garage, and pull-in trips may end at a midpoint of the route.
- **For a route with multiple terminals, it is advisable to make space for more than one terminal on the blocking sheet.** It is very easy to introduce errors by cross blocking trips from one outer terminal to the other, especially when arrival or leave times at both terminals are similar. A recommended format designed to guard against this kind of mistake is shown later in this example.
- **The easiest way to block interlined trips is to set up a sheet showing arrive and leave times of all routes at a particular terminal.** From that sheet, trips are matched and the blocking process progresses to other terminals and other blocking opportunities using another match-up sheet. An example of a **"match-up" sheet** is shown later in this section.

The following pages include the Route 96 map, the master schedule (headway sheet) for Route 96, and a sample blocking sheet form that displays multiple terminals. The first step is to develop an initial set of blocks from the master schedule and record these on the blocking sheet form.

Route 96A- Pasco Ave.



HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

Part 1

NORTHBOUND SOUTHBOUND

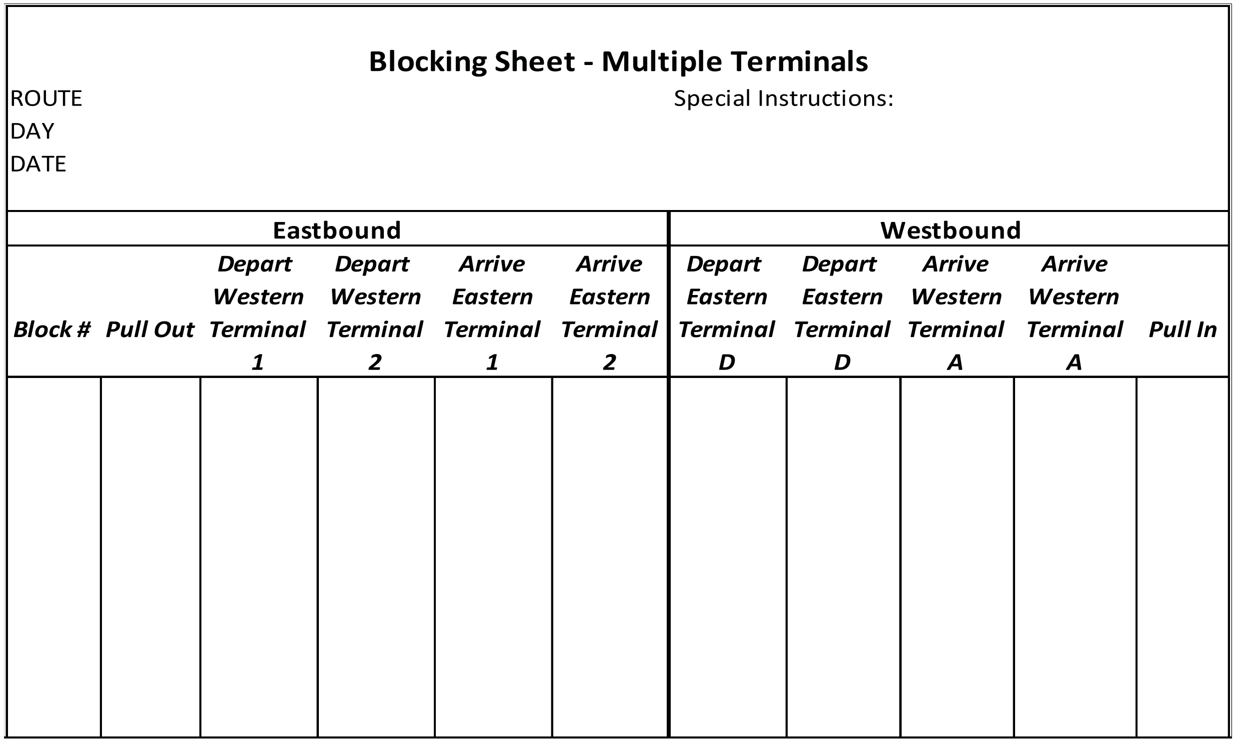
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
	4:10								4:20	4:28	4:35	4:43		4:53	5:05	0	
	3:45	4:05		4:18	4:26	4:33	4:41		4:50	4:58	5:05	5:13		5:23	5:35	0	
	4:55								5:05	5:13	5:20	5:28	5:37		5:49	0	
	4:15	4:35		4:48	4:56	5:03	5:11		5:20	5:29	5:37	5:47		5:57	6:05	0	
	4:39		4:59	5:08	5:16	5:23	5:31		5:35	5:44	5:52	6:02	6:12		6:19	0	
		5:05		5:19	5:29	5:37	5:46		5:50	5:59	6:07	6:17		6:27	6:45	0	
	4:59		5:19	5:29	5:39	5:47	5:56		6:05	6:14	6:22	6:32	6:42		6:57	0	
		5:35		5:49	5:59	6:07	6:16		6:20	6:29	6:37	6:47		6:57	7:05	0	
			5:49	5:59	6:09	6:17	6:26		6:35	6:44	6:52	7:02	7:12		7:17	0	
		6:05		6:19	6:29	6:37	6:46		6:50	7:01	7:10	7:21		7:32	7:45	0	
			6:19	6:29	6:39	6:47	6:56		7:05	7:16	7:25	7:36	7:46		7:57	0	
	6:05	6:25		6:39	6:50	6:59	7:10		7:15	7:26	7:35	7:46		7:57	8:05	0	
	6:17		6:37	6:49	7:00	7:09	7:20		7:25	7:36	7:45	7:56	8:06		8:23	0	
		6:45		6:59	7:10	7:19	7:30		7:35	7:46	7:55	8:06		8:17	8:35	0	
			6:57	7:09	7:20	7:29	7:40		7:45	7:56	8:05	8:16	8:26			0	8:46
		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37	9:05	0	
			7:17	7:29	7:40	7:49	8:00		8:05	8:16	8:25	8:36	8:46		8:53	0	
	7:05	7:25		7:39	7:50	7:59	8:10		8:15	8:26	8:35	8:46		8:57		0	9:17
	7:17		7:37	7:49	8:00	8:09	8:20		8:25	8:36	8:45	8:56	9:06		9:23	0	
		7:45		7:59	8:10	8:19	8:30		8:35	8:46	8:55	9:06		9:17	9:35	0	
			7:57	8:09	8:20	8:29	8:40		8:45	8:56	9:05	9:16	9:26			0	9:46
		8:05		8:19	8:30	8:39	8:50		8:55	9:06	9:15	9:26		9:37		0	9:57
			8:23	8:34	8:44	8:52	9:02		9:07	9:18	9:27	9:38	9:48		9:53	0	
		8:35		8:48	8:58	9:06	9:16		9:22	9:31	9:38	9:48		9:59	10:05	0	
			8:53	9:04	9:14	9:21	9:31		9:37	9:46	9:53	10:03	10:13		10:23	0	
		9:05		9:18	9:28	9:35	9:44		9:52	10:01	10:08	10:18		10:29	10:35	0	
			9:23	9:33	9:43	9:50	9:59		10:07	10:16	10:23	10:33	10:43		10:53	0	
		9:35		9:48	9:58	10:05	10:14		10:22	10:31	10:38	10:48		10:59	11:05	0	
			9:53	10:03	10:13	10:20	10:29		10:37	10:46	10:53	11:03	11:13		11:23	0	
		10:05		10:18	10:28	10:35	10:44		10:52	11:01	11:08	11:18		11:29	11:35	0	
			10:23	10:33	10:43	10:50	10:59		11:07	11:16	11:23	11:33	11:43		11:53	0	
		10:35		10:48	10:58	11:05	11:14		11:22	11:31	11:38	11:48		11:59	12:05	0	
			10:53	11:03	11:13	11:20	11:29		11:37	11:46	11:53	12:03	12:13		12:23	0	
		11:05		11:18	11:28	11:35	11:44		11:52	12:01	12:08	12:18		12:29	12:35	0	
			11:23	11:33	11:43	11:50	11:59		12:07	12:16	12:23	12:33	12:43		12:53	0	
		11:35		11:48	11:58	12:05	12:14		12:22	12:31	12:38	12:48		12:59	13:05	0	
			11:53	12:03	12:13	12:20	12:29		12:37	12:46	12:53	13:03	13:13		13:23	0	
		12:05		12:18	12:28	12:35	12:44		12:52	13:01	13:08	13:18		13:29	13:35	0	
			12:23	12:33	12:43	12:50	12:59		13:07	13:16	13:23	13:33	13:43		13:53	0	
		12:35		12:48	12:58	13:05	13:14		13:22	13:31	13:38	13:48		13:59	14:05	0	
			12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:13		14:23	0	
		13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:29	14:35	0	
			13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:43		14:53	0	

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

Part 1

	NORTHBOUND								SOUTHBOUND								
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
		13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		14:59	15:05	0	
			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:13		15:23	0	
		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:29	15:35	0	
			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:43		15:48	0	
		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		15:59	16:05	0	
	15:23								15:33	15:43	15:50	16:01	16:11		16:15	0	
			14:53	15:03	15:14	15:21	15:31		15:45	15:55	16:02	16:13		16:24	16:32	0	
		15:05		15:18	15:29	15:36	15:46		15:57	16:07	16:14	16:25	16:35		16:45	0	
			15:23	15:33	15:44	15:51	16:01		16:09	16:19	16:26	16:37		16:48	16:52	0	
		15:35		15:48	15:59	16:06	16:16		16:20	16:31	16:39	16:50	17:01		17:05	0	
			15:48	15:58	16:09	16:16	16:26		16:30	16:41	16:49	17:00		17:12	17:15	0	
	15:53			16:08	16:19	16:26	16:36		16:40	16:51	16:59	17:10	17:21		17:28	0	
		16:05		16:18	16:29	16:36	16:46		16:50	17:01	17:09	17:20		17:32	17:36	0	
			16:15	16:25	16:36	16:44	16:55		17:00	17:11	17:19	17:30	17:41		17:53	0	
	16:20			16:35	16:46	16:54	17:05		17:10	17:21	17:29	17:40		17:52	18:05	0	
		16:32		16:45	16:56	17:04	17:15		17:20	17:31	17:39	17:50	18:01			0	18:21
			16:45	16:55	17:06	17:14	17:25		17:30	17:40	17:48	17:58		18:10	18:35	0	
		16:52		17:05	17:16	17:24	17:35		17:40	17:50	17:58	18:08	18:19		18:23	0	
			17:05	17:15	17:26	17:34	17:45		17:52	18:02	18:10	18:20		18:32		0	18:52
		17:15		17:28	17:39	17:47	17:58		18:05	18:15	18:23	18:33	18:44		18:53	0	
			17:28	17:38	17:49	17:57	18:08									0	18:18
		17:36		17:49	17:59	18:06	18:15		18:20	18:30	18:38	18:48		19:00	19:05	0	
			17:53	18:03	18:13	18:20	18:29		18:35	18:45	18:53	19:03	19:14		19:23	0	
		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:15		19:26	19:35	0	
			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:30	19:40		19:53	0	
		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:50		20:01	20:06	0	
			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:10	20:20		20:28	0	
		19:05		19:18	19:28	19:35	19:44									0	19:54
			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:30		20:41	20:46	0	
		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:50	21:00		21:08	0	
			19:53	20:03	20:12	20:19	20:26									0	20:36
		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:10		21:21	21:26	0	
			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48	0	
		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06	0	
			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28	0	
		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46	0	
			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08	0	
		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26	0	
			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48	0	
		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06	0	
			23:08	23:18	23:26	23:32	23:39									0	23:49
		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36		0	0:56
			23:48	23:58	0:06	0:12	0:19									0	0:29
		0:06		0:18	0:26	0:32	0:39									0	0:49



Blocking Sheet - Multiple Terminals

ROUTE
DAY
DATE

Special Instructions:

Eastbound						Westbound				
Block #	***Pull Out***	***Depart Western Terminal 1***	***Depart Western Terminal 2***	***Arrive Eastern Terminal 1***	***Arrive Eastern Terminal 2***	***Depart Eastern Terminal D***	***Depart Eastern Terminal D***	***Arrive Western Terminal A***	***Arrive Western Terminal A***	***Pull In***

In blocking Route 96, we will use the convention of numbering the blocks in the order of pull-out from the garage. The headway sheet shows the first pull-out at 3:45 AM for a 4:05 northbound trip from Libby/Wishram. Number this as block 9601 and assign this block to all subsequent hooked trips. The headway sheet below shows the first few 9601 trips. Your filled-in headway sheet will show that the block will operate all day, with a final trip northbound at 0:06, returning to the garage at 0:49.

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

	NORTHBOUND								SOUTHBOUND								
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
	4:10								4:20	4:28	4:35	4:43		4:53	5:05	0	
9601	3:45	4:05		4:18	4:26	4:33	4:41		4:50	4:58	5:05	5:13		5:23	5:35	9601	
	4:55								5:05	5:13	5:20	5:28	5:37		5:49	0	
	4:15	4:35		4:48	4:56	5:03	5:11		5:20	5:29	5:37	5:47		5:57	6:05	0	
	4:39		4:59	5:08	5:16	5:23	5:31		5:35	5:44	5:52	6:02	6:12		6:19	0	
		5:05		5:19	5:29	5:37	5:46		5:50	5:59	6:07	6:17		6:27	6:45	0	
	4:59		5:19	5:29	5:39	5:47	5:56		6:05	6:14	6:22	6:32	6:42		6:57	0	
9601		5:35		5:49	5:59	6:07	6:16		6:20	6:29	6:37	6:47		6:57	7:05	9601	
			5:49	5:59	6:09	6:17	6:26		6:35	6:44	6:52	7:02	7:12		7:17	0	
		6:05		6:19	6:29	6:37	6:46		6:50	7:01	7:10	7:21		7:32	7:45	0	
			6:19	6:29	6:39	6:47	6:56		7:05	7:16	7:25	7:36	7:46		7:57	0	
	6:05	6:25		6:39	6:50	6:59	7:10		7:15	7:26	7:35	7:46		7:57	8:05	0	
	6:17		6:37	6:49	7:00	7:09	7:20		7:25	7:36	7:45	7:56	8:06		8:23	0	
		6:45		6:59	7:10	7:19	7:30		7:35	7:46	7:55	8:06		8:17	8:35	0	
			6:57	7:09	7:20	7:29	7:40		7:45	7:56	8:05	8:16	8:26			0	8:46
9601		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37	9:05	9601	

The sample blocking sheet has been customized for Route 96, and the 9601 entries are shown below, including all the trips assigned to this block. If you use formulas (as recommended) in constructing the blocking sheet, you have already found that this sheet is different from the blocking sheet in the Route 97 examples—the formulas change! This is because running time and layover time change throughout the day.

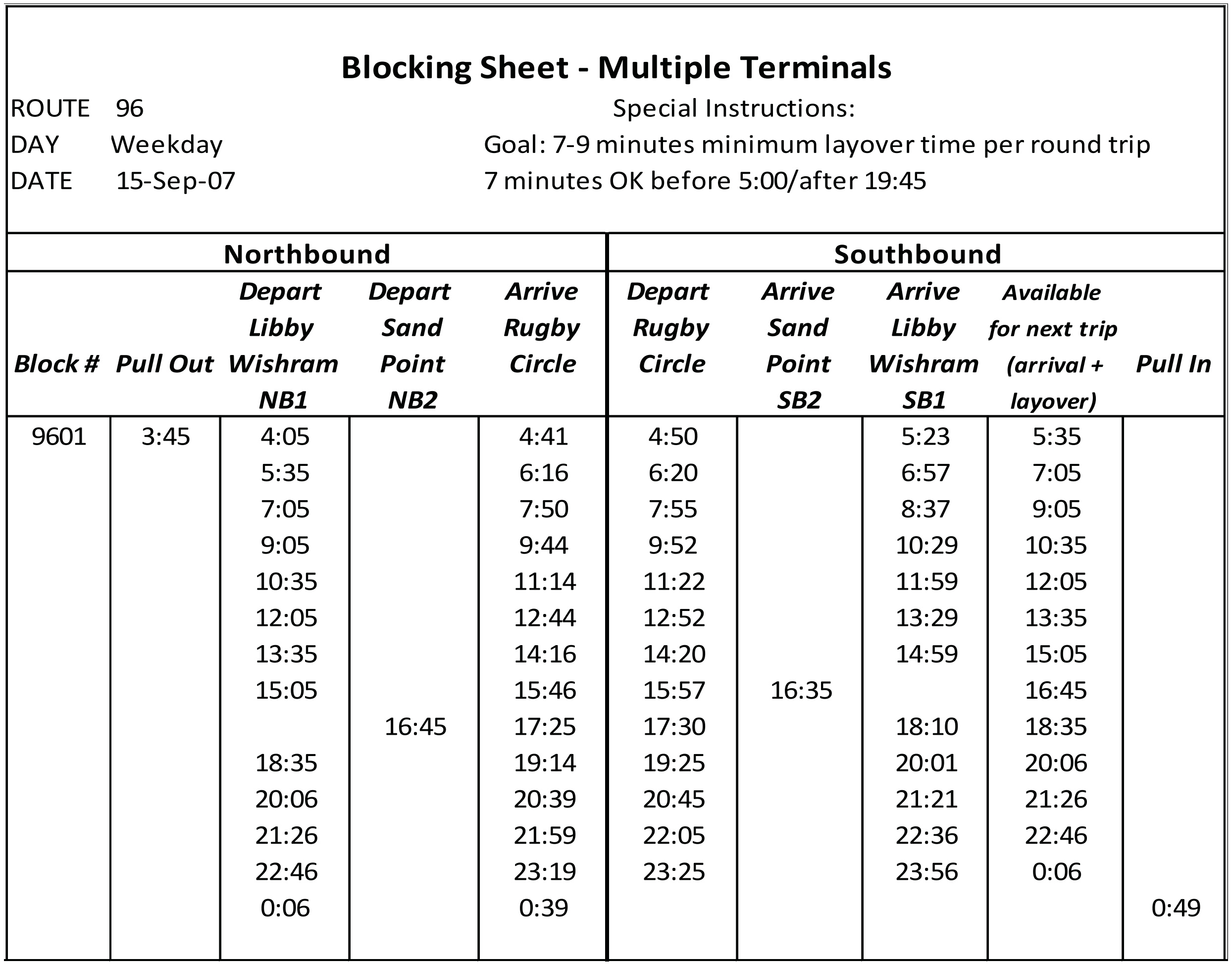
You can also see that most but not all 9601 trips serve the Libby/Wishram terminal instead of the Sand Point terminal. Other blocks could have a more even distribution of trips between the

paddle

The drivers schedule for the day including all scheduled time points and notes or reminders to the operator.

two terminals, or may have a pattern similar to 9601. The **paddle** usually includes a reminder regarding the appropriate headsign to use for each trip.

Finally, you will note that there are some long layovers in the schedule, particularly at times when headways are in transition. The trip arriving at Libby/Wishram at 8:37 has a 28-minute layover, while the trip arriving at 18:10 has a 25-minute layover. In cases where meal breaks are required, long layovers are often scheduled to accommodate these breaks. After we are done with blocking, we should review the blocks to see if there are better hooks. In terms of minimum layover, the 13:35 northbound trip has four minutes at one end and six minutes at the other end, meeting the minimum required layover of nine minutes per round trip.



Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

		Northbound			**Southbound**				
Block #	***Pull Out***	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9601	3:45	4:05		4:41	4:50		5:23	5:35	
		5:35		6:16	6:20		6:57	7:05	
		7:05		7:50	7:55		8:37	9:05	
		9:05		9:44	9:52		10:29	10:35	
		10:35		11:14	11:22		11:59	12:05	
		12:05		12:44	12:52		13:29	13:35	
		13:35		14:16	14:20		14:59	15:05	
		15:05		15:46	15:57	16:35		16:45	
			16:45	17:25	17:30		18:10	18:35	
		18:35		19:14	19:25		20:01	20:06	
		20:06		20:39	20:45		21:21	21:26	
		21:26		21:59	22:05		22:36	22:46	
		22:46		23:19	23:25		23:56	0:06	
		0:06		0:39					0:49

Next, add the second block. The next pull-out is at 4:10 to Rugby Circle, so this will become Block 9602. Block 9602 also provides all-day service, with a final trip northbound at 19:05, pulling in at 19:44. The third block (9603) pulls out at 4:15 and is also an all-day block. Block 9604 pulls out at 4:39. After adding these blocks, the headway sheet (showing early trips only) and blocking sheet appear as follows:

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

	NORTHBOUND								SOUTHBOUND								
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
9602	4:10								4:20	4:28	4:35	4:43		4:53	5:05	9602	
9601	3:45	4:05		4:18	4:26	4:33	4:41		4:50	4:58	5:05	5:13		5:23	5:35	9601	
	4:55								5:05	5:13	5:20	5:28	5:37		5:49	0	
9603	4:15	4:35		4:48	4:56	5:03	5:11		5:20	5:29	5:37	5:47		5:57	6:05	9603	
9604	4:39		4:59	5:08	5:16	5:23	5:31		5:35	5:44	5:52	6:02	6:12		6:19	9604	
9602		5:05		5:19	5:29	5:37	5:46		5:50	5:59	6:07	6:17		6:27	6:45	9602	
	4:59		5:19	5:29	5:39	5:47	5:56		6:05	6:14	6:22	6:32	6:42		6:57	0	
9601		5:35		5:49	5:59	6:07	6:16		6:20	6:29	6:37	6:47		6:57	7:05	9601	
			5:49	5:59	6:09	6:17	6:26		6:35	6:44	6:52	7:02	7:12		7:17	0	
9603		6:05		6:19	6:29	6:37	6:46		6:50	7:01	7:10	7:21		7:32	7:45	9603	
9604			6:19	6:29	6:39	6:47	6:56		7:05	7:16	7:25	7:36	7:46		7:57	9604	
	6:05	6:25		6:39	6:50	6:59	7:10		7:15	7:26	7:35	7:46		7:57	8:05	0	
	6:17		6:37	6:49	7:00	7:09	7:20		7:25	7:36	7:45	7:56	8:06		8:23	0	
9602		6:45		6:59	7:10	7:19	7:30		7:35	7:46	7:55	8:06		8:17	8:35	9602	
			6:57	7:09	7:20	7:29	7:40		7:45	7:56	8:05	8:16	8:26			0	8:46
9601		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37	9:05	9601	
			7:17	7:29	7:40	7:49	8:00		8:05	8:16	8:25	8:36	8:46		8:53	0	
	7:05	7:25		7:39	7:50	7:59	8:10		8:15	8:26	8:35	8:46		8:57		0	9:17
	7:17		7:37	7:49	8:00	8:09	8:20		8:25	8:36	8:45	8:56	9:06		9:23	0	
9603		7:45		7:59	8:10	8:19	8:30		8:35	8:46	8:55	9:06		9:17	9:35	9603	
9604			7:57	8:09	8:20	8:29	8:40		8:45	8:56	9:05	9:16	9:26			9604	9:46
		8:05		8:19	8:30	8:39	8:50		8:55	9:06	9:15	9:26		9:37		0	9:57
			8:23	8:34	8:44	8:52	9:02		9:07	9:18	9:27	9:38	9:48		9:53	0	
9602		8:35		8:48	8:58	9:06	9:16		9:22	9:31	9:38	9:48		9:59	10:05	9602	

Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

Northbound					Southbound				
Block #	***Pull Out***	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9601	3:45	4:05		4:41	4:50		5:23	5:35	
		5:35		6:16	6:20		6:57	7:05	
		7:05		7:50	7:55		8:37	9:05	
		9:05		9:44	9:52		10:29	10:35	
		10:35		11:14	11:22		11:59	12:05	
		12:05		12:44	12:52		13:29	13:35	
		13:35		14:16	14:20		14:59	15:05	
		15:05		15:46	15:57	16:35		16:45	
			16:45	17:25	17:30		18:10	18:35	
		18:35		19:14	19:25		20:01	20:06	
		20:06		20:39	20:45		21:21	21:26	
		21:26		21:59	22:05		22:36	22:46	
		22:46		23:19	23:25		23:56	0:06	
		0:06		0:39					0:49
9602	4:10				4:20		4:53	5:05	
		5:05		5:46	5:50		6:27	6:45	
		6:45		7:30	7:35		8:17	8:35	
		8:35		9:16	9:22		9:59	10:05	
		10:05		10:44	10:52		11:29	11:35	
		11:35		12:14	12:22		12:59	13:05	
		13:05		13:44	13:50		14:29	14:35	
		14:35		15:16	15:20		15:59	16:05	
		16:05		16:46	16:50		17:32	17:36	
		17:36		18:15	18:20		19:00	19:05	
		19:05		19:44					19:54
9603	4:15	4:35		5:11	5:20		5:57	6:05	
		6:05		6:46	6:50		7:32	7:45	
		7:45		8:30	8:35		9:17	9:35	
		9:35		10:14	10:22		10:59	11:05	
		11:05		11:44	11:52		12:29	12:35	
		12:35		13:14	13:22		13:59	14:05	
		14:05		14:46	14:50		15:29	15:35	
		15:35		16:16	16:20	17:01		17:05	
			17:05	17:45	17:52		18:32		18:52
9604	4:39		4:59	5:31	5:35	6:12		6:19	
			6:19	6:56	7:05	7:46		7:57	
			7:57	8:40	8:45	9:26			9:46

As the blocking process continues, you may notice the following:

- Blocks pull out to multiple locations. This was true even in our simple example in the basic blocking section. With two branches, the first four blocks pull out to three different locations to begin revenue service. As the process continues into the afternoon, some PM blocks will pull out to a mid-route location.
- Some blocks operate all day, while others operate in only one peak period.
- In the peak periods, layover time can approach or even drop below the minimum 10% level. The 16:05 round-trip on block 9602 and the 15:35 round trip on block 9603 have only eight minutes of layover time (four at each terminal). With a round-trip running time of 82 minutes, the layover time rounds up to 10% and so may be acceptable. As noted previously, several agencies have work rules that allow slight “cheating” on layover times during peak periods. Note that in both cases, layover times before and after the round-trips in question are at least five minutes.

The final blocking sheet and headway sheet for Route 96 are shown below. All blocks are filled in on the blocking sheet, and each trip on the headway sheet is assigned to a block.

Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

		Northbound			Southbound				
Block #	***Pull Out***	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9601	3:45	4:05		4:41	4:50		5:23	5:35	
		5:35		6:16	6:20		6:57	7:05	
		7:05		7:50	7:55		8:37	9:05	
		9:05		9:44	9:52		10:29	10:35	
		10:35		11:14	11:22		11:59	12:05	
		12:05		12:44	12:52		13:29	13:35	
		13:35		14:16	14:20		14:59	15:05	
		15:05		15:46	15:57	16:35		16:45	
			16:45	17:25	17:30		18:10	18:35	
		18:35		19:14	19:25		20:01	20:06	
		20:06		20:39	20:45		21:21	21:26	
		21:26		21:59	22:05		22:36	22:46	
		22:46		23:19	23:25		23:56	0:06	
		0:06		0:39					0:49
9602	4:10				4:20		4:53	5:05	
		5:05		5:46	5:50		6:27	6:45	
		6:45		7:30	7:35		8:17	8:35	
		8:35		9:16	9:22		9:59	10:05	
		10:05		10:44	10:52		11:29	11:35	
		11:35		12:14	12:22		12:59	13:05	
		13:05		13:44	13:50		14:29	14:35	
		14:35		15:16	15:20		15:59	16:05	
		16:05		16:46	16:50		17:32	17:36	
		17:36		18:15	18:20		19:00	19:05	
		19:05		19:44					19:54
9603	4:15	4:35		5:11	5:20		5:57	6:05	
		6:05		6:46	6:50		7:32	7:45	
		7:45		8:30	8:35		9:17	9:35	
		9:35		10:14	10:22		10:59	11:05	
		11:05		11:44	11:52		12:29	12:35	
		12:35		13:14	13:22		13:59	14:05	
		14:05		14:46	14:50		15:29	15:35	
		15:35		16:16	16:20	17:01		17:05	
			17:05	17:45	17:52		18:32		18:52
9604	4:39		4:59	5:31	5:35	6:12		6:19	
			6:19	6:56	7:05	7:46		7:57	
			7:57	8:40	8:45	9:26			9:46

Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

Northbound						Southbound				
Block #	***Pull Out***	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Depart Pasco Essex midroute***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9605	4:55					5:05	5:37		5:49	
			5:49		6:26	6:35	7:12		7:17	
			7:17		8:00	8:05	8:46		8:53	
			8:53		9:31	9:37	10:13		10:23	
			10:23		10:59	11:07	11:43		11:53	
			11:53		12:29	12:37	13:13		13:23	
			13:23		13:59	14:07	14:43		14:53	
			14:53		15:31	15:45		16:24	16:32	
		16:32			17:15	17:20	18:01			18:21
9606	4:59		5:19		5:56	6:05	6:42		6:57	
			6:57		7:40	7:45	8:26			8:46
9607	6:05	6:25			7:10	7:15		7:57	8:05	
		8:05			8:50	8:55		9:37		9:57
9608	6:17		6:37		7:20	7:25	8:06		8:23	
			8:23		9:02	9:07	9:48		9:53	
			9:53		10:29	10:37	11:13		11:23	
			11:23		11:59	12:07	12:43		12:53	
			12:53		13:29	13:35	14:13		14:23	
			14:23		15:01	15:05	15:43		15:48	
			15:48		16:26	16:30		17:12	17:15	
		17:15			17:58	18:05	18:44		18:53	
			18:53		19:29	19:45	20:20		20:28	
			20:28		20:59	21:05	21:35		21:48	
			21:48		22:19	22:25	22:55		23:08	
			23:08		23:39					23:49
9609	7:05	7:25			8:10	8:15		8:57		9:17
9610	7:17		7:37		8:20	8:25	9:06		9:23	
			9:23		9:59	10:07	10:43		10:53	
			10:53		11:29	11:37	12:13		12:23	
			12:23		12:59	13:07	13:43		13:53	
			13:53		14:31	14:35	15:13		15:23	
			15:23		16:01	16:09		16:48	16:52	
		16:52			17:35	17:40	18:19		18:23	
			18:23		18:59	19:05	19:40		19:53	
			19:53		20:26					20:36

Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

Northbound						Southbound				
Block #	**Pull Out**	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Depart Pasco Essex midroute***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9611	15:23					15:33	16:11		16:15	
			16:15		16:55	16:59	17:41		17:53	
			17:53		18:29	18:35	19:14		19:23	
			19:23		19:59	20:05		20:41	20:46	
		20:46			21:19	21:25		21:56	22:06	
		22:06			22:39	22:45		23:16	23:26	
		23:26			23:59	0:05		0:36		0:56
9612	15:53			16:08	16:36	16:40	17:21		17:28	
			17:28		18:08					18:18
9613	16:20			16:35	17:05	17:10		17:52	18:05	
		18:05			18:44	18:50		19:26	19:35	
		19:35			20:14	20:25	21:01		21:08	
			21:08		21:39	21:45	22:15		22:28	
			22:28		22:59	23:05	23:35		23:48	
			23:48		0:19					0:29

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

	NORTHBOUND								SOUTHBOUND								
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
9602	4:10								4:20	4:28	4:35	4:43		4:53	5:05	9602	
9601	3:45	4:05		4:18	4:26	4:33	4:41		4:50	4:58	5:05	5:13		5:23	5:35	9601	
9605	4:55								5:05	5:13	5:20	5:28	5:37		5:49	9605	
9603	4:15	4:35		4:48	4:56	5:03	5:11		5:20	5:29	5:37	5:47		5:57	6:05	9603	
9604	4:39		4:59	5:08	5:16	5:23	5:31		5:35	5:44	5:52	6:02	6:12		6:19	9604	
9602		5:05		5:19	5:29	5:37	5:46		5:50	5:59	6:07	6:17		6:27	6:45	9602	
9606	4:59		5:19	5:29	5:39	5:47	5:56		6:05	6:14	6:22	6:32	6:42		6:57	9606	
9601		5:35		5:49	5:59	6:07	6:16		6:20	6:29	6:37	6:47		6:57	7:05	9601	
9605			5:49	5:59	6:09	6:17	6:26		6:35	6:44	6:52	7:02	7:12		7:17	9605	
9603		6:05		6:19	6:29	6:37	6:46		6:50	7:01	7:10	7:21		7:32	7:45	9603	
9604			6:19	6:29	6:39	6:47	6:56		7:05	7:16	7:25	7:36	7:46		7:57	9604	
9607	6:05	6:25		6:39	6:50	6:59	7:10		7:15	7:26	7:35	7:46		7:57	8:05	9607	
9608	6:17		6:37	6:49	7:00	7:09	7:20		7:25	7:36	7:45	7:56	8:06		8:23	9608	
9602		6:45		6:59	7:10	7:19	7:30		7:35	7:46	7:55	8:06		8:17	8:35	9602	
9606			6:57	7:09	7:20	7:29	7:40		7:45	7:56	8:05	8:16	8:26			9606	8:46
9601		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37	9:05	9601	
9605			7:17	7:29	7:40	7:49	8:00		8:05	8:16	8:25	8:36	8:46		8:53	9605	
9609	7:05	7:25		7:39	7:50	7:59	8:10		8:15	8:26	8:35	8:46		8:57		9609	9:17
9610	7:17		7:37	7:49	8:00	8:09	8:20		8:25	8:36	8:45	8:56	9:06		9:23	9610	
9603		7:45		7:59	8:10	8:19	8:30		8:35	8:46	8:55	9:06		9:17	9:35	9603	
9604			7:57	8:09	8:20	8:29	8:40		8:45	8:56	9:05	9:16	9:26			9604	9:46
9607		8:05		8:19	8:30	8:39	8:50		8:55	9:06	9:15	9:26		9:37		9607	9:57
9608			8:23	8:34	8:44	8:52	9:02		9:07	9:18	9:27	9:38	9:48		9:53	9608	
9602		8:35		8:48	8:58	9:06	9:16		9:22	9:31	9:38	9:48		9:59	10:05	9602	
9605			8:53	9:04	9:14	9:21	9:31		9:37	9:46	9:53	10:03	10:13		10:23	9605	
9601		9:05		9:18	9:28	9:35	9:44		9:52	10:01	10:08	10:18		10:29	10:35	9601	
9610			9:23	9:33	9:43	9:50	9:59		10:07	10:16	10:23	10:33	10:43		10:53	9610	
9603		9:35		9:48	9:58	10:05	10:14		10:22	10:31	10:38	10:48		10:59	11:05	9603	
9608			9:53	10:03	10:13	10:20	10:29		10:37	10:46	10:53	11:03	11:13		11:23	9608	
9602		10:05		10:18	10:28	10:35	10:44		10:52	11:01	11:08	11:18		11:29	11:35	9602	
9605			10:23	10:33	10:43	10:50	10:59		11:07	11:16	11:23	11:33	11:43		11:53	9605	
9601		10:35		10:48	10:58	11:05	11:14		11:22	11:31	11:38	11:48		11:59	12:05	9601	
9610			10:53	11:03	11:13	11:20	11:29		11:37	11:46	11:53	12:03	12:13		12:23	9610	
9603		11:05		11:18	11:28	11:35	11:44		11:52	12:01	12:08	12:18		12:29	12:35	9603	
9608			11:23	11:33	11:43	11:50	11:59		12:07	12:16	12:23	12:33	12:43		12:53	9608	
9602		11:35		11:48	11:58	12:05	12:14		12:22	12:31	12:38	12:48		12:59	13:05	9602	
9605			11:53	12:03	12:13	12:20	12:29		12:37	12:46	12:53	13:03	13:13		13:23	9605	
9601		12:05		12:18	12:28	12:35	12:44		12:52	13:01	13:08	13:18		13:29	13:35	9601	
9610			12:23	12:33	12:43	12:50	12:59		13:07	13:16	13:23	13:33	13:43		13:53	9610	
9603		12:35		12:48	12:58	13:05	13:14		13:22	13:31	13:38	13:48		13:59	14:05	9603	
9608			12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:13		14:23	9608	
9602		13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:29	14:35	9602	
9605			13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:43		14:53	9605	

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

NORTHBOUND									SOUTHBOUND								
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
9601		13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		14:59	15:05	9601	
9610			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:13		15:23	9610	
9603		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:29	15:35	9603	
9608			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:43		15:48	9608	
9602		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		15:59	16:05	9602	
9611	15:23								15:33	15:43	15:50	16:01	16:11		16:15	9611	
9605			14:53	15:03	15:14	15:21	15:31		15:45	15:55	16:02	16:13		16:24	16:32	9605	
9601		15:05		15:18	15:29	15:36	15:46		15:57	16:07	16:14	16:25	16:35		16:45	9601	
9610			15:23	15:33	15:44	15:51	16:01		16:09	16:19	16:26	16:37		16:48	16:52	9610	
9603		15:35		15:48	15:59	16:06	16:16		16:20	16:31	16:39	16:50	17:01		17:05	9603	
9608			15:48	15:58	16:09	16:16	16:26		16:30	16:41	16:49	17:00		17:12	17:15	9608	
9612	15:53			16:08	16:19	16:26	16:36		16:40	16:51	16:59	17:10	17:21		17:28	9612	
9602		16:05		16:18	16:29	16:36	16:46		16:50	17:01	17:09	17:20		17:32	17:36	9602	
9611			16:15	16:25	16:36	16:44	16:55		17:00	17:11	17:19	17:30	17:41		17:53	9611	
9613	16:20			16:35	16:46	16:54	17:05		17:10	17:21	17:29	17:40		17:52	18:05	9613	
9605		16:32		16:45	16:56	17:04	17:15		17:20	17:31	17:39	17:50	18:01			9605	18:21
9601			16:45	16:55	17:06	17:14	17:25		17:30	17:40	17:48	17:58		18:10	18:35	9601	
9610		16:52		17:05	17:16	17:24	17:35		17:40	17:50	17:58	18:08	18:19		18:23	9610	
9603			17:05	17:15	17:26	17:34	17:45		17:52	18:02	18:10	18:20		18:32		9603	18:52
9608		17:15		17:28	17:39	17:47	17:58		18:05	18:15	18:23	18:33	18:44		18:53	9608	
9612			17:28	17:38	17:49	17:57	18:08									9612	18:18
9602		17:36		17:49	17:59	18:06	18:15		18:20	18:30	18:38	18:48		19:00	19:05	9602	
9611			17:53	18:03	18:13	18:20	18:29		18:35	18:45	18:53	19:03	19:14		19:23	9611	
9613		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:15		19:26	19:35	9613	
9610			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:30	19:40		19:53	9610	
9601		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:50		20:01	20:06	9601	
9608			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:10	20:20		20:28	9608	
9602		19:05		19:18	19:28	19:35	19:44									9602	19:54
9611			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:30		20:41	20:46	9611	
9613		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:50	21:00		21:08	9613	
9610			19:53	20:03	20:12	20:19	20:26									9610	20:36
9601		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:10		21:21	21:26	9601	
9608			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48	9608	
9611		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06	9611	
9613			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28	9613	
9601		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46	9601	
9608			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08	9608	
9611		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26	9611	
9613			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48	9613	
9601		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06	9601	
9608			23:08	23:18	23:26	23:32	23:39									9608	23:49
9611		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36		9611	0:56
9613			23:48	23:58	0:06	0:12	0:19									9613	0:29
9601		0:06		0:18	0:26	0:32	0:39									9601	0:49

The vehicle hours and mileage summary tables for Route 96 are presented below. The mileage summary table is more complex because of the multiple trip patterns and multiple locations where pull-outs begin service and pull-ins end service.

Hours Summary

Block	Garage Depart	Garage Arrive	Platform Hours
9601	3:45	24:49	21:04
9602	4:10	19:54	15:44
9603	4:15	18:52	14:37
9604	4:39	9:46	5:07
9605	4:55	18:21	13:26
9606	4:59	8:46	3:47
9607	6:05	9:57	3:52
9608	6:17	23:49	17:32
9609	7:05	9:17	2:12
9610	7:17	20:36	13:19
9611	15:23	0:56	9:33
9612	15:53	18:18	2:25
9613	16:20	0:29	8:09
Total			**130:47**

Mileage Summary

Block	96 NB Trips	96A NB Trips	96 NB Trips from Essex	96 SB Trips	96A SB Trips	Pull Trips Libby/Wishram	Pull Trips Sand Point	Pull Trips Pasco Essex	Pull Trips Rugby Circle	Mileage
9601	13	1		12	1	1			1	215.8
9602	10			10					2	160.0
9603	8	1		8	1	2				149.2
9604		3			3		2			54.0
9605	1	7		1	8		1		1	131.7
9606		2			2		2			39.6
9607	2			2		2				41.8
9608	1	11		1	10		1		1	175.0
9609	1			1		2				26.3
9610	1	8		1	7		1		1	131.7
9611	3	3		4	3	1			1	105.7
9612		1	1		1			1	1	25.6
9613	2	3	1	2	3			1	1	85.4
Total	**42**	**40**	**2**	**42**	**39**	**8**	**7**	**2**	**9**	**1341.7**

full-time operator

An operator available to work full-time runs and eligible to receive full benefits. A full-time operator is usually guaranteed 40 hours of work per week. Typically, full-time operators can select either a full-time run or a split run, or can choose to work on the extraboard.

part-time operator

An operator who works less than 40 hours a week. The maximum number of hours that a part-time operator can work per week is often specified in the contract. A part-time operator may not receive the full benefits of a full-time operator, and may be paid at a lower wage rate.

work hours

The total hours worked by an operator, not including fringe benefit hours such as sick leave, holiday, etc. Work hours include only labor hours associated with the requirements of putting the runs in service and operating the service.

make-up time

Time added to an operator's work hours to bring the total up to the guaranteed minimum (usually eight hours per day or 40 hours per week). Full-time operators often have an eight-hour guarantee, even if their runs are short of eight hours.

block straightening

This is the procedure of looking at blocks once the blocking process is finished and rehooking block beginnings or ends to yield blocks that will be more efficient in the runcut process. For instance, a block that is 14 hours long might be extended by swapping next trips with another block to extend to 16 hours, which would offer a better runcutting potential.

on-street relief

The process where, at a specific time during a specific trip on a block, one operator's run ends and another operator's run begins. The relief may occur at a terminal or at a designated point along the route (possibly close to the garage). On-street relief is used to minimize pull-out and pull-in miles and hours. Operators are usually paid travel time for travel between the garage and the relief point. Reliefs may also occur at the garage; these are known as "garage reliefs."

relief location

A designated point on a route where operators or crews may be scheduled to begin or end their run or a piece of their run. This can include the garage/base station itself.

Evaluating the Block

There is no single answer to how to "block" a schedule. One thing is always true—how well the blocks are cut will have a direct impact on how efficiently the driver schedules, or runs, can be built—and that translates directly to how much your service will cost.

Some things you should look for in a well-designed blocking scheme:

- Blocks between five and six hours are generally less desirable because they are not long enough to make a single work piece without significant **"make-up time"** and do not work well in split runs without resulting in considerable overtime. Look for blocks that are four hours or less or seven plus hours.
- For longer blocks, look at options that break the longer block into reasonable pieces. Avoid odd-sized blocks (13 to 15 hours).
- Avoid short PM blocks that finish at 20:00 to 22:00. These are difficult to combine with anything else.

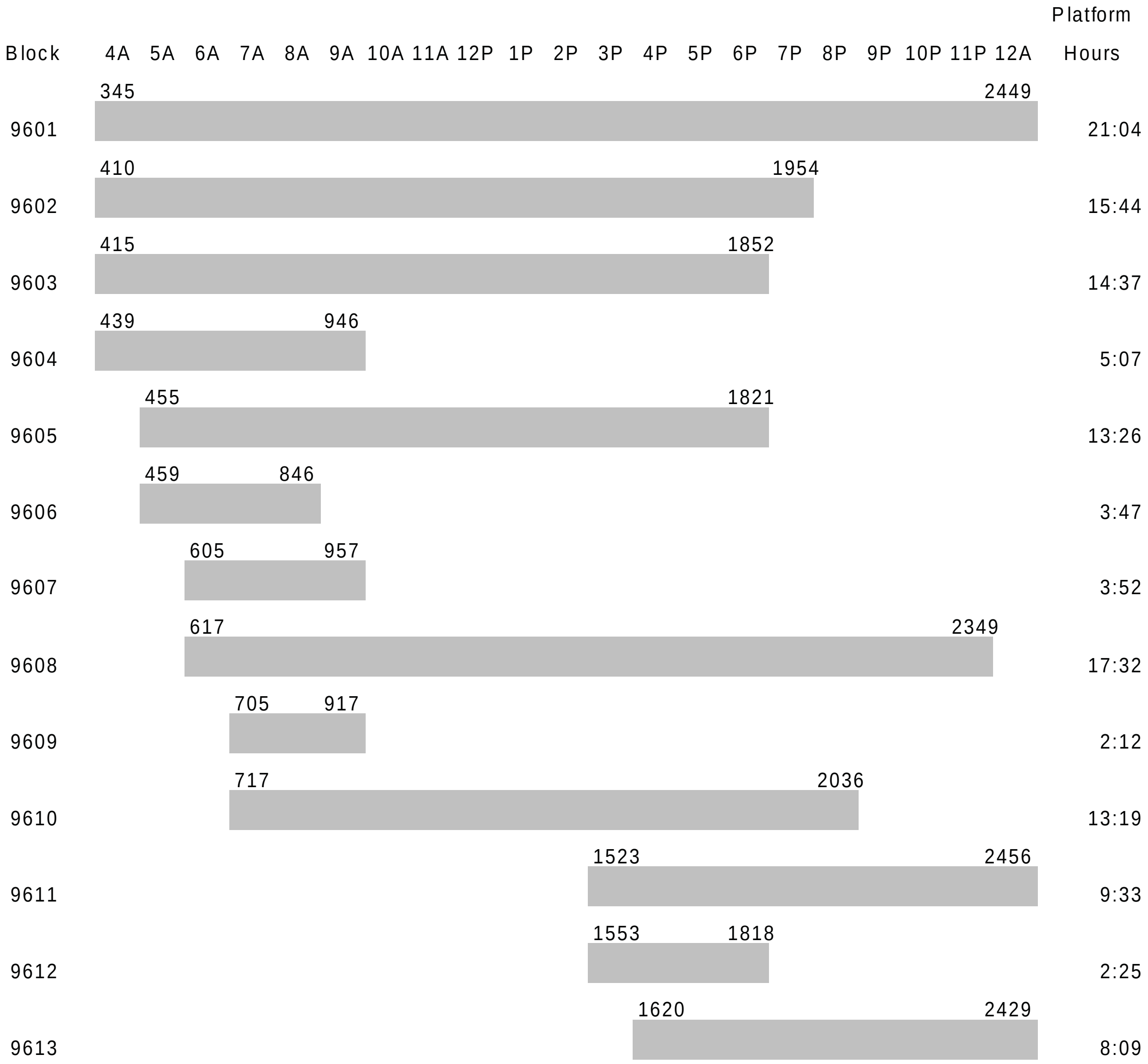
Evaluating the blocks for efficient runcutting is an example of how all elements of scheduling are interconnected. To facilitate this evaluation, block graphs are extremely useful.

Block Graphs

A graph of the initial Route 96 blocks is shown below. This block graph displays platform hours for each block. A number of observations can be made about this block graph:

- There is one block (9604 at 5:07) in the five-hour to six-hour range. This is on the low side of the range, so it may or may not be a problem.
- Blocks 9609 and 9612 are very small pieces of work. It may be possible to combine these blocks with longer blocks to create a reasonable work assignment, but reblocking to lengthen these blocks would be preferable, if possible. There are no short PM blocks that finish after 20:00.
- The longer blocks appear to lend themselves to various cutting options, given various possible **on-street relief locations**.

The next step is to evaluate ways to **"straighten" the blocks**, i.e., reblock some of the trips to ensure effective utilization of resources.


Block
4A 5A 6A 7A 8A 9A 10A 11A 12P 1P 2P 3P 4P 5P 6P 7P 8P 9P 10P 11P 12A
Platform Hours
9601 345 2449 21:04
9602 410 1954 15:44
9603 415 1852 14:37
9604 439 946 5:07
9605 455 1821 13:26
9606 459 846 3:47
9607 605 957 3:52
9608 617 2349 17:32
9609 705 917 2:12
9610 717 2036 13:19
9611 1523 2456 9:33
9612 1553 1818 2:25
9613 1620 2429 8:09

Reblocking Blocks 9601 and 9609

Block 9609 is very short, and reblocking to lengthen this block would be preferable. To identify opportunities to do so, take a very close look at trips around the time that Block 9609 pulls in. Are there any reblocking possibilities?

What if the southbound 8:15 AM trip, the last trip in Block 9609, were hooked with the 9:05 AM trip departing from Libby/Wishram? Currently this trip is hooked with an earlier trip on Block 9601. There is no problem with layover—there would be eight minutes of layover on Block 9609, which meets the minimum requirement and is 20 minutes less than currently scheduled on Block 9601. This change is shown on the headway sheet below.

HEADWAY SHEET

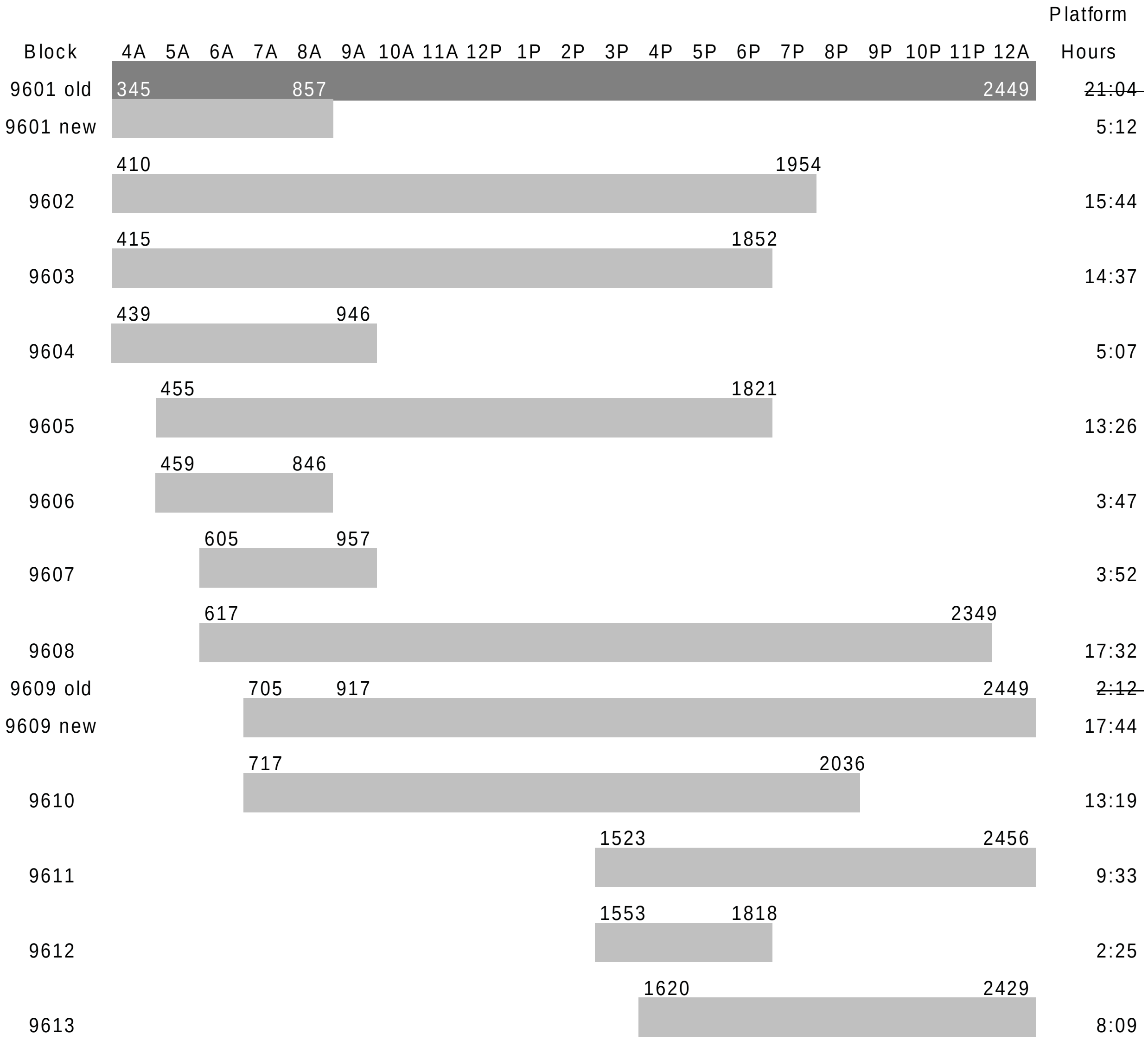
Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

	NORTHBOUND								SOUTHBOUND								
BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	NEXT TRIP	BLK	IN GAR
9601		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37		9601	8:57
9605			7:17	7:29	7:40	7:49	8:00		8:05	8:16	8:25	8:36	8:46		8:53	9605	
9609	7:05	7:25		7:39	7:50	7:59	8:10		8:15	8:26	8:35	8:46		8:57	9:05	9609	

The following changes result:

1. An eight-minute layover is now scheduled on revised Block 9609, compared to a 28-minute layover on Block 9601 before this change.
2. Block 9601 now pulls in at 8:57 AM. This could be a problem if the union contract calls for all early pull-outs to be an early straight run, but for now the block will pull in at 8:57 AM.
3. Replacing all Block 9601 trips with revised Block 9609 at 9:05 AM and afterward provides a new pull-in time for Block 9609 at 12:49 AM.
4. Revised Block 9601 is now an AM block with 4:32 platform hours.
5. Revised Block 9609 is now an all-day block with 17:14 platform hours.
6. Total platform hours are decreased by 20 minutes from 130:47 to 130:27.

This adjustment appears to be appropriate and is reflected in the revised block graph. There is a savings of 20 minutes as a result of this change.


Block
4A 5A 6A 7A 8A 9A 10A 11A 12P 1P 2P 3P 4P 5P 6P 7P 8P 9P 10P 11P 12A
Platform Hours
9601 old 345 857 2449 ~~21:04~~
9601 new 5:12
9602 410 1954 15:44
9603 415 1852 14:37
9604 439 946 5:07
9605 455 1821 13:26
9606 459 846 3:47
9607 605 957 3:52
9608 617 2349 17:32
9609 old 705 917 2449 ~~2:12~~
9609 new 17:44
9610 717 2036 13:19
9611 1523 2456 9:33
9612 1553 1818 2:25
9613 1620 2429 8:09

swing time

The elapsed time (usually unpaid) between the pieces of a split run. If swing time is paid, it is sometimes called "inside time."

Block 9612 is still troubling because it is only 2:00 in length. This could be an afternoon piece of a split run, but it could involve excessive **swing time**. Is there anything that could be changed?

Study the afternoon portion of the headway sheet on the next page. Block 9612 pulls out at 15:53 to a mid-route location at Pasco & Essex. In the previous reblocking example, we found a different way to hook trips together that actually reduced platform hours. The trips around the first trip on 9612 do not offer a similar opportunity.

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

	NORTHBOUND								SOUTHBOUND								
BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	NEXT TRIP	BLK	IN GAR
9601		13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		14:59	15:05	9601	
9610			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:13		15:23	9610	
9603		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:29	15:35	9603	
9608			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:43		15:48	9608	
9602		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		15:59	16:05	9602	
9611	15:23								15:33	15:43	15:50	16:01	16:11		16:15	9611	
9605			14:53	15:03	15:14	15:21	15:31		15:45	15:55	16:02	16:13		16:24	16:32	9605	
9601		15:05		15:18	15:29	15:36	15:46		15:57	16:07	16:14	16:25	16:35		16:45	9601	
9610			15:23	15:33	15:44	15:51	16:01		16:09	16:19	16:26	16:37		16:48	16:52	9610	
9603		15:35		15:48	15:59	16:06	16:16		16:20	16:31	16:39	16:50	17:01		17:05	9603	
9608			15:48	15:58	16:09	16:16	16:26		16:30	16:41	16:49	17:00		17:12	17:15	9608	
9612	15:53			16:08	16:19	16:26	16:36		16:40	16:51	16:59	17:10	17:21		17:28	9612	
9602		16:05		16:18	16:29	16:36	16:46		16:50	17:01	17:09	17:20		17:32	17:36	9602	
9611			16:15	16:25	16:36	16:44	16:55		17:00	17:11	17:19	17:30	17:41		17:53	9611	
9613	16:20			16:35	16:46	16:54	17:05		17:10	17:21	17:29	17:40		17:52	18:05	9613	
9605		16:32		16:45	16:56	17:04	17:15		17:20	17:31	17:39	17:50	18:01			9605	18:21
9601			16:45	16:55	17:06	17:14	17:25		17:30	17:40	17:48	17:58		18:10	18:35	9601	
9610		16:52		17:05	17:16	17:24	17:35		17:40	17:50	17:58	18:08	18:19		18:23	9610	
9603			17:05	17:15	17:26	17:34	17:45		17:52	18:02	18:10	18:20		18:32		9603	18:52
9608		17:15		17:28	17:39	17:47	17:58		18:05	18:15	18:23	18:33	18:44		18:53	9608	
9612			17:28	17:38	17:49	17:57	18:08									9612	18:18
9602		17:36		17:49	17:59	18:06	18:15		18:20	18:30	18:38	18:48		19:00	19:05	9602	
9611			17:53	18:03	18:13	18:20	18:29		18:35	18:45	18:53	19:03	19:14		19:23	9611	
9613		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:15		19:26	19:35	9613	
9610			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:30	19:40		19:53	9610	
9601		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:50		20:01	20:06	9601	
9608			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:10	20:20		20:28	9608	
9602		19:05		19:18	19:28	19:35	19:44									9602	19:54
9611			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:30		20:41	20:46	9611	
9613		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:50	21:00		21:08	9613	
9610			19:53	20:03	20:12	20:19	20:26									9610	20:36
9601		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:10		21:21	21:26	9601	
9608			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48	9608	
9611		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06	9611	
9613			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28	9613	
9601		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46	9601	
9608			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08	9608	
9611		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26	9611	
9613			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48	9613	
9601		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06	9601	
9608			23:08	23:18	23:26	23:32	23:39									9608	23:49
9611		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36		9611	0:56
9613			23:48	23:58	0:06	0:12	0:19									9613	0:29
9601		0:06		0:18	0:26	0:32	0:39									9601	0:49

What if block 9612 pulled out 10 minutes earlier and covered the preceding trip now served by block 9608? Block 9608 would then have an additional 10 minutes layover time for the trip ending at Sand Point at 15:43, and would begin its next northbound trip at 15:58, covering the trip now served by block 9612. This change is highlighted below.

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

	NORTHBOUND								SOUTHBOUND								
BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	NEXT TRIP	BLK	IN GAR
9608			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:43		15:58	9608	
9602		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		15:59	16:05	9602	
9611	15:23								15:33	15:43	15:50	16:01	16:11		16:15	9611	
9605			14:53	15:03	15:14	15:21	15:31		15:45	15:55	16:02	16:13		16:24	16:32	9605	
9609		15:05		15:18	15:29	15:36	15:46		15:57	16:07	16:14	16:25	16:35		16:45	9609	
9610			15:23	15:33	15:44	15:51	16:01		16:09	16:19	16:26	16:37		16:48	16:52	9610	
9603		15:35		15:48	15:59	16:06	16:16		16:20	16:31	16:39	16:50	17:01		17:05	9603	
9612	15:43			15:58	16:09	16:16	16:26		16:30	16:41	16:49	17:00		17:12	17:15	9612	
9608			15:58	16:08	16:19	16:26	16:36		16:40	16:51	16:59	17:10	17:21		17:28	9608	

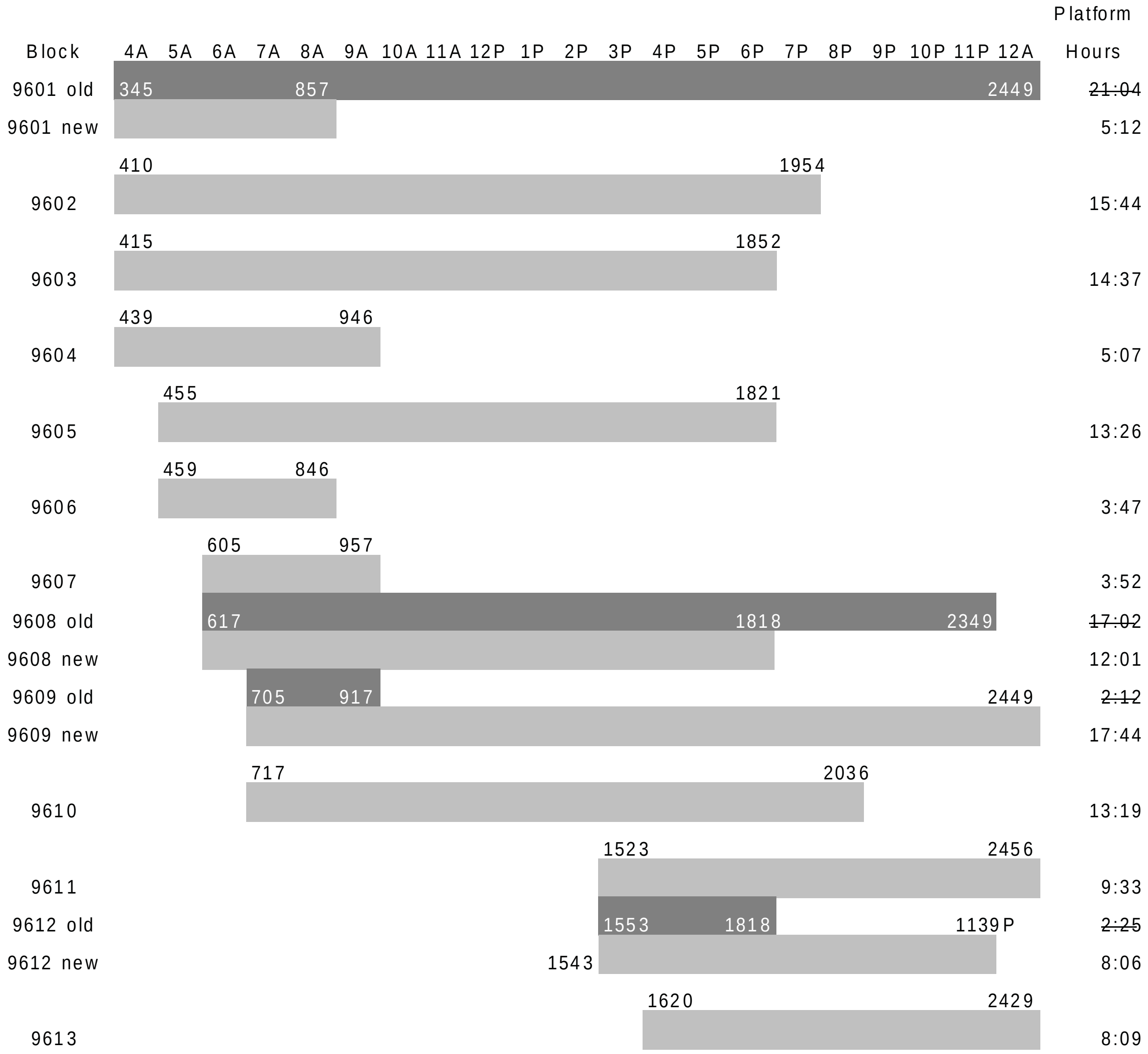
The following changes result:

1. A 15-minute layover is now scheduled on revised Block 9608, compared to a five-minute layover before this change.
2. Block 9612 now pulls out at 15:43 instead of 15:53.
3. The pattern of trip departures at Sand Point is altered, with a 15:58 departure replacing the former 15:48 departure. The next departure (not shown above) is at 16:15, resulting in an uneven headway.
4. Replacing all Block 9608 trips after 15:43 with revised Block 9612 provides a new pull-in time for Block 9608 at 18:18.
5. Revised Block 9612 is now a PM block with 7:41 platform hours, as shown on the block graph below.
6. Revised Block 9608 is now an all-day block with 11:31 platform hours, as shown below.
7. Total platform hours are increased by 10 minutes from 130:27 to 130:37.

The block graph on the next page shows both the 9601 and 9609 swap and the 9608 and 9612 swap. These changes appear to be reasonable, and are included in the final headway and blocking sheets. There are still a few blocks of less than optimal length (i.e., between five

Tip Blocks that are close to eight hours or 16 hours are most efficient for runcutting. Very short blocks, less than 6 hours long are candidates for reblocking.

and six hours and between 13 and 15 hours). Attempts to re-size these blocks have resulted in unwarranted increases in platform hours, so for now we will leave these for further evaluation during the runcutting phase. The final vehicle hours and mileage summary tables are also shown.



Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

Northbound						Southbound				
Block #	***Pull Out***	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Depart Pasco Essex midroute***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9601	3:45	4:05			4:41	4:50		5:23	5:35	
		5:35			6:16	6:20		6:57	7:05	
		7:05			7:50	7:55		8:37		8:57
9602	4:10					4:20		4:53	5:05	
		5:05			5:46	5:50		6:27	6:45	
		6:45			7:30	7:35		8:17	8:35	
		8:35			9:16	9:22		9:59	10:05	
		10:05			10:44	10:52		11:29	11:35	
		11:35			12:14	12:22		12:59	13:05	
		13:05			13:44	13:50		14:29	14:35	
		14:35			15:16	15:20		15:59	16:05	
		16:05			16:46	16:50		17:32	17:36	
		17:36			18:15	18:20		19:00	19:05	
		19:05			19:44					19:54
9603	4:15	4:35			5:11	5:20		5:57	6:05	
		6:05			6:46	6:50		7:32	7:45	
		7:45			8:30	8:35		9:17	9:35	
		9:35			10:14	10:22		10:59	11:05	
		11:05			11:44	11:52		12:29	12:35	
		12:35			13:14	13:22		13:59	14:05	
		14:05			14:46	14:50		15:29	15:35	
		15:35			16:16	16:20	17:01		17:05	
			17:05		17:45	17:52		18:32		18:52
9604	4:39		4:59		5:31	5:35	6:12		6:19	
			6:19		6:56	7:05	7:46		7:57	
			7:57		8:40	8:45	9:26			9:46

Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

Northbound						Southbound				
Block #	**Pull Out**	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Depart Pasco Essex midroute***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9605	4:55					5:05	5:37		5:49	
			5:49		6:26	6:35	7:12		7:17	
			7:17		8:00	8:05	8:46		8:53	
			8:53		9:31	9:37	10:13		10:23	
			10:23		10:59	11:07	11:43		11:53	
			11:53		12:29	12:37	13:13		13:23	
			13:23		13:59	14:07	14:43		14:53	
			14:53		15:31	15:45		16:24	16:32	
		16:32			17:15	17:20	18:01			18:21
9606	4:59		5:19		5:56	6:05	6:42		6:57	
			6:57		7:40	7:45	8:26			8:46
9607	6:05	6:25			7:10	7:15		7:57	8:05	
		8:05			8:50	8:55		9:37		9:57
9608	6:17		6:37		7:20	7:25	8:06		8:23	
			8:23		9:02	9:07	9:48		9:53	
			9:53		10:29	10:37	11:13		11:23	
			11:23		11:59	12:07	12:43		12:53	
			12:53		13:29	13:35	14:13		14:23	
			14:23		15:01	15:05	15:43		15:58	
			15:58		16:36	16:40	17:21		17:28	
			17:28		18:08					18:18
9609	7:05	7:25			8:10	8:15		8:57	9:05	
		9:05			9:44	9:52		10:29	10:35	
		10:35			11:14	11:22		11:59	12:05	
		12:05			12:44	12:52		13:29	13:35	
		13:35			14:16	14:20		14:59	15:05	
		15:05			15:46	15:57	16:35		16:45	
			16:45		17:25	17:30		18:10	18:35	
		18:35			19:14	19:25		20:01	20:06	
		20:06			20:39	20:45		21:21	21:26	
		21:26			21:59	22:05		22:36	22:46	
		22:46			23:19	23:25		23:56	0:06	
		0:06			0:39					0:49

Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

Northbound						Southbound				
Block #	*Pull Out*	*Depart Libby Wishram NB1*	*Depart Sand Point NB2*	*Depart Pasco Essex midroute*	*Arrive Rugby Circle*	*Depart Rugby Circle*	*Arrive Sand Point SB2*	*Arrive Libby Wishram SB1*	*Available for next trip (arrival + layover)*	*Pull In*
9610	7:17		7:37		8:20	8:25	9:06		9:23	
			9:23		9:59	10:07	10:43		10:53	
			10:53		11:29	11:37	12:13		12:23	
			12:23		12:59	13:07	13:43		13:53	
			13:53		14:31	14:35	15:13		15:23	
			15:23		16:01	16:09		16:48	16:52	
		16:52			17:35	17:40	18:19		18:23	
			18:23		18:59	19:05	19:40		19:53	
			19:53		20:26					20:36
9611	15:23					15:33	16:11		16:15	
			16:15		16:55	16:59	17:41		17:53	
			17:53		18:29	18:35	19:14		19:23	
			19:23		19:59	20:05		20:41	20:46	
		20:46			21:19	21:25		21:56	22:06	
		22:06			22:39	22:45		23:16	23:26	
		23:26			23:59	0:05		0:36		0:56
9612	15:43			15:58	16:26	16:30		17:12	17:15	
		17:15			17:58	18:05	18:44		18:53	
			18:53		19:29	19:45	20:20		20:28	
			20:28		20:59	21:05	21:35		21:48	
			21:48		22:19	22:25	22:55		23:08	
			23:08		23:39					23:49
9613	16:20			16:35	17:05	17:10		17:52	18:05	
		18:05			18:44	18:50		19:26	19:35	
		19:35			20:14	20:25	21:01		21:08	
			21:08		21:39	21:45	22:15		22:28	
			22:28		22:59	23:05	23:35		23:48	
			23:48		0:19					0:29

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

NORTHBOUND									SOUTHBOUND								
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
9602	4:10								4:20	4:28	4:35	4:43		4:53	5:05	9602	
9601	3:45	4:05		4:18	4:26	4:33	4:41		4:50	4:58	5:05	5:13		5:23	5:35	9601	
9605	4:55								5:05	5:13	5:20	5:28	5:37		5:49	9605	
9603	4:15	4:35		4:48	4:56	5:03	5:11		5:20	5:29	5:37	5:47		5:57	6:05	9603	
9604	4:39		4:59	5:08	5:16	5:23	5:31		5:35	5:44	5:52	6:02	6:12		6:19	9604	
9602		5:05		5:19	5:29	5:37	5:46		5:50	5:59	6:07	6:17		6:27	6:45	9602	
9606	4:59		5:19	5:29	5:39	5:47	5:56		6:05	6:14	6:22	6:32	6:42		6:57	9606	
9601		5:35		5:49	5:59	6:07	6:16		6:20	6:29	6:37	6:47		6:57	7:05	9601	
9605			5:49	5:59	6:09	6:17	6:26		6:35	6:44	6:52	7:02	7:12		7:17	9605	
9603		6:05		6:19	6:29	6:37	6:46		6:50	7:01	7:10	7:21		7:32	7:45	9603	
9604			6:19	6:29	6:39	6:47	6:56		7:05	7:16	7:25	7:36	7:46		7:57	9604	
9607	6:05	6:25		6:39	6:50	6:59	7:10		7:15	7:26	7:35	7:46		7:57	8:05	9607	
9608	6:17		6:37	6:49	7:00	7:09	7:20		7:25	7:36	7:45	7:56	8:06		8:23	9608	
9602		6:45		6:59	7:10	7:19	7:30		7:35	7:46	7:55	8:06		8:17	8:35	9602	
9606			6:57	7:09	7:20	7:29	7:40		7:45	7:56	8:05	8:16	8:26			9606	8:46
9601		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37		9601	8:57
9605			7:17	7:29	7:40	7:49	8:00		8:05	8:16	8:25	8:36	8:46		8:53	9605	
9609	7:05	7:25		7:39	7:50	7:59	8:10		8:15	8:26	8:35	8:46		8:57	9:05	9609	
9610	7:17		7:37	7:49	8:00	8:09	8:20		8:25	8:36	8:45	8:56	9:06		9:23	9610	
9603		7:45		7:59	8:10	8:19	8:30		8:35	8:46	8:55	9:06		9:17	9:35	9603	
9604			7:57	8:09	8:20	8:29	8:40		8:45	8:56	9:05	9:16	9:26			9604	9:46
9607		8:05		8:19	8:30	8:39	8:50		8:55	9:06	9:15	9:26		9:37		9607	9:57
9608			8:23	8:34	8:44	8:52	9:02		9:07	9:18	9:27	9:38	9:48		9:53	9608	
9602		8:35		8:48	8:58	9:06	9:16		9:22	9:31	9:38	9:48		9:59	10:05	9602	
9605			8:53	9:04	9:14	9:21	9:31		9:37	9:46	9:53	10:03	10:13		10:23	9605	
9609		9:05		9:18	9:28	9:35	9:44		9:52	10:01	10:08	10:18		10:29	10:35	9609	
9610			9:23	9:33	9:43	9:50	9:59		10:07	10:16	10:23	10:33	10:43		10:53	9610	
9603		9:35		9:48	9:58	10:05	10:14		10:22	10:31	10:38	10:48		10:59	11:05	9603	
9608			9:53	10:03	10:13	10:20	10:29		10:37	10:46	10:53	11:03	11:13		11:23	9608	
9602		10:05		10:18	10:28	10:35	10:44		10:52	11:01	11:08	11:18		11:29	11:35	9602	
9605			10:23	10:33	10:43	10:50	10:59		11:07	11:16	11:23	11:33	11:43		11:53	9605	
9609		10:35		10:48	10:58	11:05	11:14		11:22	11:31	11:38	11:48		11:59	12:05	9609	
9610			10:53	11:03	11:13	11:20	11:29		11:37	11:46	11:53	12:03	12:13		12:23	9610	
9603		11:05		11:18	11:28	11:35	11:44		11:52	12:01	12:08	12:18		12:29	12:35	9603	
9608			11:23	11:33	11:43	11:50	11:59		12:07	12:16	12:23	12:33	12:43		12:53	9608	
9602		11:35		11:48	11:58	12:05	12:14		12:22	12:31	12:38	12:48		12:59	13:05	9602	
9605			11:53	12:03	12:13	12:20	12:29		12:37	12:46	12:53	13:03	13:13		13:23	9605	
9609		12:05		12:18	12:28	12:35	12:44		12:52	13:01	13:08	13:18		13:29	13:35	9609	
9610			12:23	12:33	12:43	12:50	12:59		13:07	13:16	13:23	13:33	13:43		13:53	9610	
9603		12:35		12:48	12:58	13:05	13:14		13:22	13:31	13:38	13:48		13:59	14:05	9603	
9608			12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:13		14:23	9608	
9602		13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:29	14:35	9602	
9605			13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:43		14:53	9605	

HEADWAY SHEET

Route 96 IN EFF: September 15, 2007
MONDAY THRU FRIDAY

NORTHBOUND SOUTHBOUND

BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	NEXT TRIP	BLK	IN GAR
9609		13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		14:59	15:05	9609	
9610			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:13		15:23	9610	
9603		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:29	15:35	9603	
9608			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:43		15:58	9608	
9602		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		15:59	16:05	9602	
9611	15:23								15:33	15:43	15:50	16:01	16:11		16:15	9611	
9605			14:53	15:03	15:14	15:21	15:31		15:45	15:55	16:02	16:13		16:24	16:32	9605	
9609		15:05		15:18	15:29	15:36	15:46		15:57	16:07	16:14	16:25	16:35		16:45	9609	
9610			15:23	15:33	15:44	15:51	16:01		16:09	16:19	16:26	16:37		16:48	16:52	9610	
9603		15:35		15:48	15:59	16:06	16:16		16:20	16:31	16:39	16:50	17:01		17:05	9603	
9612	15:43			15:58	16:09	16:16	16:26		16:30	16:41	16:49	17:00		17:12	17:15	9612	
9608			15:58	16:08	16:19	16:26	16:36		16:40	16:51	16:59	17:10	17:21		17:28	9608	
9602		16:05		16:18	16:29	16:36	16:46		16:50	17:01	17:09	17:20		17:32	17:36	9602	
9611			16:15	16:25	16:36	16:44	16:55		17:00	17:11	17:19	17:30	17:41		17:53	9611	
9613	16:20			16:35	16:46	16:54	17:05		17:10	17:21	17:29	17:40		17:52	18:05	9613	
9605		16:32		16:45	16:56	17:04	17:15		17:20	17:31	17:39	17:50	18:01			9605	18:21
9609			16:45	16:55	17:06	17:14	17:25		17:30	17:40	17:48	17:58		18:10	18:35	9609	
9610		16:52		17:05	17:16	17:24	17:35		17:40	17:50	17:58	18:08	18:19		18:23	9610	
9603			17:05	17:15	17:26	17:34	17:45		17:52	18:02	18:10	18:20		18:32		9603	18:52
9612		17:15		17:28	17:39	17:47	17:58		18:05	18:15	18:23	18:33	18:44		18:53	9612	
9608			17:28	17:38	17:49	17:57	18:08									9608	18:18
9602		17:36		17:49	17:59	18:06	18:15		18:20	18:30	18:38	18:48		19:00	19:05	9602	
9611			17:53	18:03	18:13	18:20	18:29		18:35	18:45	18:53	19:03	19:14		19:23	9611	
9613		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:15		19:26	19:35	9613	
9610			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:30	19:40		19:53	9610	
9609		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:50		20:01	20:06	9609	
9612			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:10	20:20		20:28	9612	
9602		19:05		19:18	19:28	19:35	19:44									9602	19:54
9611			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:30		20:41	20:46	9611	
9613		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:50	21:00		21:08	9613	
9610			19:53	20:03	20:12	20:19	20:26									9610	20:36
9609		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:10		21:21	21:26	9609	
9612			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48	9612	
9611		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06	9611	
9613			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28	9613	
9609		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46	9609	
9612			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08	9612	
9611		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26	9611	
9613			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48	9613	
9609		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06	9609	
9612			23:08	23:18	23:26	23:32	23:39									9612	23:49
9611		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36		9611	0:56
9613			23:48	23:58	0:06	0:12	0:19									9613	0:29
9609		0:06		0:18	0:26	0:32	0:39									9609	0:49

Hours Summary

Block	Garage Depart	Garage Arrive	Platform Hours
9601	3:45	8:57	5:12
9602	4:10	19:54	15:44
9603	4:15	18:52	14:37
9604	4:39	9:46	5:07
9605	4:55	18:21	13:26
9606	4:59	8:46	3:47
9607	6:05	9:57	3:52
9608	6:17	18:18	12:01
9609	7:05	0:49	17:44
9610	7:17	20:36	13:19
9611	15:23	0:56	9:33
9612	15:43	23:49	8:06
9613	16:20	0:29	8:09
Total			**130:37**

Mileage Summary

Block	96 NB Trips	96A NB Trips	96 NB Trips from Essex	96 SB Trips	96A SB Trips	Pull Trips Libby/Wishram	Pull Trips Sand Point	Pull Trips Pasco Essex	Pull Trips Rugby Circle	Mileage
9601	3			3		2				57.3
9602	10			10					2	160.0
9603	8	1		8	1	2				149.2
9604		3			3		2			54.0
9605	1	7		1	8		1		1	131.7
9606		2			2		2			39.6
9607	2			2		2				41.8
9608		8			7		1		1	116.2
9609	11	1		10	1	1			1	184.8
9610	1	8		1	7		1		1	131.7
9611	3	3		4	3	1			1	105.7
9612	1	4	1	1	4			1	1	84.4
9613	2	3	1	2	3			1	1	85.4
Total	**42**	**40**	**2**	**42**	**39**	**8**	**7**	**2**	**9**	**1341.7**

Deadheading vs. Running in Service

The Route 96 example has introduced complexities typical of those facing schedulers, including multiple terminals, running times that change throughout the day, and considerations regarding other elements of the scheduling process, especially runcutting. An interesting aspect that deserves additional discussion is pull-out and pull-in locations. The revised blocks resulted in two pull-outs (at 15:43 and 16:20) to Pasco & Essex, which is not a terminal but rather a location along the route. Are there benefits in doing so? And why did we do this instead of starting these trips at one of the terminals?

The simplest answer is that these pull-outs occur early in the PM peak, when more frequent service is needed along the core of the route but not yet along the branches. The mid-route pull-out puts service in the place where it is needed, when it is needed. By focusing service where it is needed and by avoiding over-serving the branches, the mid-route pull-out minimizes platform hours. The pull-out could have gone into service at Rugby Circle at the northern end of the route, as the 15:23 pull-out did, but then the northbound headways could not have been reduced to 10 minutes at 15:30. Use of mid-route pull-outs allows the scheduler to provide required service while minimizing the cost to do so. The “complexity” introduced by this is typically the definition of an additional deadhead path between the garage and the route.

More broadly, are there advantages to deadheading versus running in service? Depending on the route and garage location, there is not always a choice, but are there times when one is preferable to the other?

Advantages of deadheading include:

- **Simplicity.** The bus travels directly to the location where service is needed. Invariably, this is the least expensive option.
- **Consistency.** At the end of revenue service, deadheading from terminals back to the garage for pull-ins ensures that the revenue trip is completed to the terminal. Pulling in from mid-route locations may force a same-route transfer.

Advantages of running in service instead of deadheading include:

- **Maximizing service available to riders.** If a pull-out or pull-in can operate in revenue service partway to or from the garage, this provides added service for riders. Put another way, this increases the ratio of revenue hours to platform hours.
- **Flexibility.** As seen in the Route 96 example, running in service can allow the scheduler to provide the required service while minimizing costs.
- **Funding considerations.** Some agencies routinely maximize revenue miles or revenue hours because one (or both) of these measures is a component in a funding formula.

Interlining

Earlier in this chapter, we mentioned that the easiest way to block interlined routes is to set up a sheet showing arrive and leave times of all routes at a particular terminal. The Route 96 example was only a single route, so you did not have a chance to consider interlining opportunities.

Interlining opportunities are greatest at terminals served by a number of routes. In this example, Rugby Circle is a transit center served by Routes 1, 10, and 20 in addition to Route 96. Route 1 operates every half-hour during peak periods and every hour during the midday, with a round-trip running time of 55 minutes. Routes 10 and 20 operate every hour, with a round-trip running time of roughly 80 minutes. Both routes have school trips. No trips are currently interlined.

The example of a "match-up" sheet is shown below. This is the PM peak portion of the sheet, showing every arrival and departure scheduled at Rugby Circle between 3 and 6 PM.

MATCH-UP SHEET

Location: Rugby Circle IN EFF: September 15, 2007

MONDAY THRU FRIDAY

ARRIVALS				DEPARTURES		
Route	Block	Arr Time		Route	Block	Dep Time
20	2002	14:24		20	2002	15:05
10	1001	14:54		10	1001	15:35
1	101	15:00		1	101	15:05
96	608	15:01		96	9608	15:05
20S	2004	15:10				
96	9602	15:16		96	9605	15:20
10S	1004	15:20				
				96	9611	15:33
				1	104	15:35
20	2001	15:24		20	2001	16:05
96	9605	15:31		96	9605	15:45
96	9609	15:46		96	9609	15:57
10	1002	15:56		10	1002	16:35
1	101	16:00		1	101	16:05
96	9610	16:01		96	9610	16:09
96	9603	16:16		96	9603	16:20
96	9612	16:26		96	9612	16:30
20	2002	16:26		20	2002	17:05
1	104	16:30		1	104	16:35
96	9608	16:36		96	9608	16:40
96	9602	16:46		96	9602	16:50
96	9611	16:55		96	9611	17:00
10	1001	16:56		10	1001	17:35
1	101	17:00		1	101	17:05
96	9613	17:05		96	9613	17:10
96	9605	17:15		96	9605	17:20
96	9609	17:25		96	9609	17:30
20	2001	17:26		20	2001	18:05
1	104	17:30		1	104	17:35
96	9610	17:35		96	9610	17:40
96	9603	17:45		96	9603	17:52
10	1002	17:56		10	1002	18:35
96	9612	17:58		96	9612	18:05
1	101	18:00		1	101	18:05

Tip Interlining is a great tool for reducing costs and vehicle requirements, but should be used sparingly—avoiding complexity unless it adds value.

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The match-up sheet is designed to list arrivals in order and to keep blocks on the same line of text. Any departure without an arrival is a pull-out, and any arrival without a departure is a pull-in. On the sheet, the school trips (10S and 20S) pull in after making the school trip, and Route 96 and Route 1 each has a pull-out beginning service at Rugby Circle.

From a scheduler's perspective, the chief advantage of interlining is the ability to minimize the resources needed to operate a given schedule. Both school trips are using a bus to make a single trip, while two other buses are pulling out to this location to provide more frequent peak-period service. If you can interline a school trip with a trip on another block, you will save a bus.

Looking at the blocking diagram, you can interline both school trips with other trips. Interline the 20S trip arriving at 15:10 with the Route 96 trip leaving at 15:33. The 20S trip will now be part of block 9611. Interline the 10S trip arriving at 15:20 with the Route 1 trip leaving at 15:35. The 10S trip will now be part of block 104. This interlining saves two PM pullouts: blocks 1004 and 2004 are no longer needed.

Another use for the match-up sheet is to spot long layovers and explore interlining possibilities to minimize layover. Can you identify any long layovers on the match-up sheet?

The first two lines of the match-up sheet show that Route 10 and Route 20 both have 40-minute layovers (you might have guessed this already, given the 80-minute round-trip running time and the 60-minute headway on both routes). This may be an opportunity to interline all trips on the two routes (known as through-routing, as noted earlier). Route 20 arrives at approximately :25 and leaves at :05 every hour, while Route 10 arrives at approximately :55 and leaves at :35 every hour.

Would through-routing work on these two routes? Even when running time is greatest (Route 10 arrivals at 15:56 and 16:56 and Route 20 arrivals at 16:26 and 17:26), layover time would be nine minutes, or 11% of the 81-minute running time.

The changes to the school trips and Routes 10 and 20 are highlighted on the revised match-up sheet. The school trips have been assigned to their new blocks, and blocks 1004 and 2004 are no longer on the schedule. There are three blocks (1001, 1002, and 1003) on the through-routed Routes 10 and 20. Block 1003 has been added, but blocks 2001 and 2002 are no longer on the schedule. Thus, the through-routing has saved a bus on the combined Routes 10 and 20.

Notice that no arrival or departure times have changed on any trip. Without affecting the schedule at all, you have saved two PM pull-outs and one all-day pull-out. This is an example of the powerful impact of interlining.

Interlining may not be able to produce savings in a small transit system where, for example, all routes leave the downtown terminal at the same time every 30 minutes. In this situation, however, interlining can play a role by evening out the work load. If one route is tight for time on several trips while another route has plenty of time in its schedule, interlining the two routes (all day or in peak periods only) can help to ensure that no operator faces a situation of consistently minimal layovers.

MATCH-UP SHEET - REVISED

Location: Rugby Circle IN EFF: September 15, 2007

MONDAY THRU FRIDAY

ARRIVALS				DEPARTURES		
Route	Block	Arr Time		Route	Block	Dep Time
20	1002	14:24		10	1002	14:35
10	1001	14:54		20	1001	15:05
1	101	15:00		1	101	15:05
96	608	15:01		96	9608	15:05
20S	9611	15:10		96	9611	15:33
96	9602	15:16		96	9605	15:20
10S	104	15:20		1	104	15:35
20	1003	15:24		10	1003	15:35
96	9605	15:31		96	9605	15:45
96	9609	15:46		96	9609	15:57
10	1002	15:56		20	1002	16:05
1	101	16:00		1	101	16:05
96	9610	16:01		96	9610	16:09
96	9603	16:16		96	9603	16:20
96	9612	16:26		96	9612	16:30
20	1001	16:26		10	1001	16:35
1	104	16:30		1	104	16:35
96	9608	16:36		96	9608	16:40
96	9602	16:46		96	9602	16:50
96	9611	16:55		96	9611	17:00
10	1003	16:56		20	1003	17:05
1	101	17:00		1	101	17:05
96	9613	17:05		96	9613	17:10
96	9605	17:15		96	9605	17:20
96	9609	17:25		96	9609	17:30
20	1002	17:26		10	1002	17:35
1	104	17:30		1	104	17:35
96	9610	17:35		96	9610	17:40
96	9603	17:45		96	9603	17:52
10	1001	17:55		20	1001	18:05
96	9612	17:58		96	9612	18:05
1	101	18:00		1	101	18:05

Assume in this example that Route 1 experiences delays during the peak period due to construction along the route, while Routes 10 and 20 frequently arrive at Rugby Circle a few minutes early. One solution would be to interline Route 1 trips with either Route 10 or Route 20 trips during the peak period. No operator would consistently experience less layover time than scheduled—it would happen at the end of a Route 1 trip, but more layover time than scheduled would be available at the end of the Route 10 or Route 20 trip.

Change the match-up sheet so that Route 1 trips are interlined with Routes 10 and 20. The “Revised 2” match-up sheet shows the interlined blocks.

This example becomes somewhat trickier to follow throughout the PM peak. Interlining options are not always apparent to the naked eye of a novice scheduler. Computerized scheduling software packages will sometimes identify interlining opportunities that even an experienced scheduler might miss.

As noted earlier, the extent of interlining is a matter of agency policy. Some transit agencies prefer that their operators drive as many different routes as possible, to familiarize themselves with a larger portion of the route network. Others like to keep operators on a given route, so that operators become more knowledgeable of the surrounding neighborhoods.

The examples in this section have shown the blocking process at the route level and at a transfer center where several routes meet, creating interlining options. Blocking can also be done at the garage level. A garage-level exercise would take up pages in this manual; suffice to say that computerized scheduling packages simplify this process considerably.

MATCH-UP SHEET - REVISED 2

Location: Rugby Circle IN EFF: September 15, 2007

MONDAY THRU FRIDAY

ARRIVALS				DEPARTURES		
Route	Block	Arr Time		Route	Block	Dep Time
20	1002	14:24		10	1002	14:35
10	1001	14:54		1	1001	15:05
1	101	15:00		20	101	15:05
96	608	15:01		96	9608	15:05
20S	9611	15:10		96	9611	15:33
96	9602	15:16		96	9605	15:20
10S	104	15:20		1	104	15:35
20	1003	15:24		10	1003	15:35
96	9605	15:31		96	9605	15:45
96	9609	15:46		96	9609	15:57
10	1002	15:56		1	1002	16:05
1	1001	16:00		20	1001	16:05
96	9610	16:01		96	9610	16:09
96	9603	16:16		96	9603	16:20
96	9612	16:26		96	9612	16:30
20	101	16:26		1	101	16:35
1	104	16:30		10	104	16:35
96	9608	16:36		96	9608	16:40
96	9602	16:46		96	9602	16:50
96	9611	16:55		96	9611	17:00
10	1003	16:56		1	1003	17:05
1	1002	17:00		20	1002	17:05
96	9613	17:05		96	9613	17:10
96	9605	17:15		96	9605	17:20
96	9609	17:25		96	9609	17:30
20	1001	17:26		1	1001	17:35
1	101	17:30		10	101	17:35
96	9610	17:35		96	9610	17:40
96	9603	17:45		96	9603	17:52
10	104	17:55		1	104	18:05
96	9612	17:58		96	9612	18:05
1	1003	18:00		20	1003	18:05

LEVEL 2B

End of Intermediate Blocking.

The Advanced Section of Blocking continues on the next page.

To jump to Runcutting, go to page 5-1.

4.4 Advanced Blocking

LEVEL 3

The advanced section of the Schedule Building chapter made running time changes and added a trip to Route 96 to reduce overcrowding. Both changes occurred in the PM peak. The first steps in this section are to make sure that every trip hooks properly and then begin the process of reblocking, starting at the beginning of the PM pull-outs.

It is a good practice to carry each block through to the end of the schedule as it is easy to get confused between the old blocks and the new. In this example, there is enough of a change where no block finishes its day the same as it did in the original schedule.

The final schedule is shown below, with the existing blocks from the intermediate section for all trips through the beginning of the PM peak. The blocking for Part 1 of the schedule is unchanged, because running time and headway remain the same in the AM peak and the midday period. The remainder of this section focuses on Part 2 of the Route 96 schedule.

Recall from the advanced section of Chapter 3: Schedule Building that you can expect two new PM-only blocks as a result of these changes. So you expect to end up with Block 9615, as opposed to Block 9613 at the end of the blocking exercise in the intermediate section.

SCHEDULE SHEET with adjusted running time and headways

Route 96 IN EFF:
MONDAY THRU FRIDAY
Part 1

	NORTHBOUND								SOUTHBOUND								
BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
9602	4:10								4:20	4:28	4:35	4:43		4:53	5:05	9602	
9601	3:45	4:05		4:18	4:26	4:33	4:41		4:50	4:58	5:05	5:13		5:23	5:35	9601	
9605	4:55								5:05	5:13	5:20	5:28	5:37		5:49	9605	
9603	4:15	4:35		4:48	4:56	5:03	5:11		5:20	5:29	5:37	5:47		5:57	6:05	9603	
9604	4:39		4:59	5:08	5:16	5:23	5:31		5:35	5:44	5:52	6:02	6:12		6:19	9604	
9602		5:05		5:19	5:29	5:37	5:46		5:50	5:59	6:07	6:17		6:27	6:45	9602	
9605	4:59		5:19	5:29	5:39	5:47	5:56		6:05	6:14	6:22	6:32	6:42		6:57	9605	
9601		5:35		5:49	5:59	6:07	6:16		6:20	6:29	6:37	6:47		6:57	7:05	9601	
9605			5:49	5:59	6:09	6:17	6:26		6:35	6:44	6:52	7:02	7:12		7:17	9605	
9603		6:05		6:19	6:29	6:37	6:46		6:50	7:01	7:10	7:21		7:32	7:45	9603	
9604			6:19	6:29	6:39	6:47	6:56		7:05	7:16	7:25	7:36	7:46		7:57	9604	
9607	6:05	6:25		6:39	6:50	6:59	7:10		7:15	7:26	7:35	7:46		7:57	8:05	9607	
9608	6:17		6:37	6:49	7:00	7:09	7:20		7:25	7:36	7:45	7:56	8:06		8:23	9608	
9602		6:45		6:59	7:10	7:19	7:30		7:35	7:46	7:55	8:06		8:17	8:35	9602	
9606			6:57	7:09	7:20	7:29	7:40		7:45	7:56	8:05	8:16	8:26			9606	8:46
9601		7:05		7:19	7:30	7:39	7:50		7:55	8:06	8:15	8:26		8:37		9601	8:57
9605			7:17	7:29	7:40	7:49	8:00		8:05	8:16	8:25	8:36	8:46		8:53	9605	
9609	7:05	7:25		7:39	7:50	7:59	8:10		8:15	8:26	8:35	8:46		8:57	9:05	9609	
9610	7:17		7:37	7:49	8:00	8:09	8:20		8:25	8:36	8:45	8:56	9:06		9:23	9610	
9603		7:45		7:59	8:10	8:19	8:30		8:35	8:46	8:55	9:06		9:17	9:35	9603	
9604			7:57	8:09	8:20	8:29	8:40		8:45	8:56	9:05	9:16	9:26			9604	9:46
9607		8:05		8:19	8:30	8:39	8:50		8:55	9:06	9:15	9:26		9:37		9607	9:57
9608			8:23	8:34	8:44	8:52	9:02		9:07	9:18	9:27	9:38	9:48		9:53	9608	
9602		8:35		8:48	8:58	9:06	9:16		9:22	9:32	9:40	9:50		10:01	10:05	9602	
9605			8:53	9:04	9:14	9:21	9:31		9:37	9:46	9:53	10:03	10:13		10:23	9605	
9609		9:05		9:18	9:28	9:35	9:44		9:52	10:01	10:08	10:18		10:29	10:35	9609	
9610			9:23	9:33	9:43	9:50	9:59		10:07	10:16	10:23	10:33	10:43		10:53	9610	
9603		9:35		9:48	9:58	10:05	10:14		10:22	10:31	10:38	10:48		10:59	11:05	9603	
9608			9:53	10:03	10:13	10:20	10:29		10:37	10:46	10:53	11:03	11:13		11:23	9608	
9602		10:05		10:18	10:28	10:35	10:44		10:52	11:01	11:08	11:18		11:29	11:35	9602	
9605			10:23	10:33	10:43	10:50	10:59		11:07	11:16	11:23	11:33	11:43		11:53	9605	
9609		10:35		10:48	10:58	11:05	11:14		11:22	11:31	11:38	11:48		11:59	12:05	9609	
9610			10:53	11:03	11:13	11:20	11:29		11:37	11:46	11:53	12:03	12:13		12:23	9610	
9603		11:05		11:18	11:28	11:35	11:44		11:52	12:01	12:08	12:18		12:29	12:35	9603	
9608			11:23	11:33	11:43	11:50	11:59		12:07	12:16	12:23	12:33	12:43		12:53	9608	
9602		11:35		11:48	11:58	12:05	12:14		12:22	12:31	12:38	12:48		12:59	13:05	9602	
9605			11:53	12:03	12:13	12:20	12:29		12:37	12:46	12:53	13:03	13:13		13:23	9605	
9609		12:05		12:18	12:28	12:35	12:44		12:52	13:01	13:08	13:18		13:29	13:35	9609	
9610			12:23	12:33	12:43	12:50	12:59		13:07	13:16	13:23	13:33	13:43		13:53	9610	
9603		12:35		12:48	12:58	13:05	13:14		13:22	13:31	13:38	13:48		13:59	14:05	9603	
9608			12:53	13:03	13:13	13:20	13:29		13:35	13:45	13:52	14:03	14:14		14:23	9608	
9602		13:05		13:18	13:28	13:35	13:44		13:50	14:00	14:07	14:18		14:30	14:35	9602	
9605			13:23	13:33	13:43	13:50	13:59		14:05	14:15	14:22	14:33	14:44		14:53	9605	
9609		13:35		13:48	13:59	14:06	14:16		14:20	14:30	14:37	14:48		15:00	15:05	9609	

SCHEDULE SHEET with adjusted running time and headways

Route 96 IN EFF:
MONDAY THRU FRIDAY

Part 2

					NORTHBOUND						SOUTHBOUND						
BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	NEXT TRIP	BLK	IN GAR
9610			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14		15:23	9610	
9603		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30	15:35	9603	
9608			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44		15:58	9608	
9602		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00	16:05	9602	
9611	15:23								15:33	15:44	15:52	16:03	16:15		16:23	9611	
9605			14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28	16:30	9605	
9609		15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39		16:41	9609	
9610			15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52	16:55	9610	
9603		15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05		17:08	9603	
	16:19								16:29	16:41	16:50	17:02		17:15	17:17		
9612	15:43			15:58	16:09	16:16	16:26		16:37	16:49	16:58	17:10	17:22		17:17	9612	
9608			15:58	16:08	16:19	16:26	16:36		16:45	16:57	17:06	17:18		17:31	17:40	9608	
9602		16:05		16:18	16:29	16:36	16:46		16:53	17:05	17:14	17:26	17:38		17:53	9602	
	16:11			16:26	16:38	16:46	16:57		17:01	17:13	17:22	17:34		17:47			18:07
			16:23	16:34	16:46	16:54	17:05		17:09	17:21	17:30	17:42	17:54				18:14
		16:30		16:44	16:56	17:04	17:15		17:17	17:29	17:38	17:50		18:03	18:05		
			16:41	16:52	17:04	17:12	17:23		17:25	17:37	17:46	17:58	18:10		18:23		
	16:45			17:00	17:12	17:20	17:31		17:35	17:46	17:54	18:05		18:17	18:35		
		16:55		17:09	17:21	17:29	17:40		17:45	17:56	18:04	18:15	18:26				18:46
			17:08	17:19	17:31	17:39	17:50		17:55	18:06	18:14	18:25		18:37			18:57
		17:17		17:31	17:43	17:51	18:02		18:07	18:18	18:26	18:37	18:48		18:53		
			17:28	17:39	17:51	17:59	18:10		18:20	18:31	18:39	18:50		19:02	19:05		
		17:40		17:53	18:03	18:10	18:19										18:29
			17:53	18:03	18:13	18:20	18:29		18:35	18:46	18:54	19:05	19:16		19:23		
		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:16		19:27	19:35		
			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:31	19:41		19:53		
		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:51		20:02	20:06		
			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:11	20:21		20:28		
		19:05		19:18	19:28	19:35	19:44										19:54
			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:31		20:42	20:46		
		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:51	21:01		21:08		
			19:53	20:03	20:12	20:19	20:26										20:36
		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:11		21:22	21:26		
			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48		
		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06		
			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28		
		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46		
			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08		
		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26		
			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48		
		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06		
			23:08	23:18	23:26	23:32	23:39										23:49
		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36			0:56
			23:48	23:58	0:06	0:12	0:19										0:29
		0:06		0:18	0:26	0:32	0:39										0:49

The next trip that needs to be hooked is the 16:23 departure from Sand Point (for the moment, focus on completing all the existing blocks and ignore pull-outs). This can be hooked with the 16:15 arrival on block 9611. Continue block 9611 through the rest of the day—a very short rest of the day, since 9611 now pulls in at 18:14.

Next, look at the 16:30 trip from Wishram. The only trip available to hook to this trip is the 16:28 arrival on block 9605. Two minutes layover is very tight, and at the end of the 16:30 trip, there is another two-minute layover at Rugby Circle. The work rules allow this, and our operating knowledge tells us this works on a regular basis, so assign the 16:30 trip to block 9605.

Continuing with block 9605, The 17:17 southbound trip arrives at Wishram at 18:03, and the schedule calls for it to hook with the 18:05 trip. This would be three consecutive trips with only two minutes of layover each, so try to reassign the 18:05 trip to another block and hook the 18:03 arrival with a later trip at 18:35. Continuing to hook trips would result in a pull-in time of 0:49 for block 9605. The schedule sheet on the following page shows the completed blocks 9611 and 9605.

The change in hooking trips has another side benefit. The only trip available to hook with the 18:05 trip is the 17:47 arrival at Wishram. The schedule originally called for this block to pull out at 16:11, make one round trip, and pull in at 18:07. As stressed in the intermediate blocking section, it is almost always advantageous to reblock to lengthen very short blocks. So this change ends up meeting two objectives: to provide adequate layover time and to avoid pulling out a bus for only one or two trips.

Advanced schedulers would realize at this point that the change in hooking trips creates another problem. The 18:35 trip was originally scheduled to be hooked with a block that pulls out at 16:45 and finishes its first southbound trip at 18:17. If you assign the 18:35 trip to block 9605 instead of to its original block, then you are left with a block that does only one round-trip before pulling in. A similar problem occurred in the intermediate section and was addressed by shifting blocks at the end of the exercise, but now that you are aware of the issue, you can catch it at this point before you complete the rest of the blocking, and save yourself from having to redo it later.

This is an example of how a seemingly great solution can have unexpected impacts down the road. It reinforces the importance of looking at the bigger picture while analyzing any one element of scheduling. In this case, your blocking solution is threefold:

- Keep the hook between the 18:17 arrival trip and the 18:35 departure trip.
- Hook the 17:47 arrival trip with the 18:05 departure trip.
- Pull in block 9605 after it arrives at Wishram at 18:03.

SCHEDULE SHEET with changes to blocks 9605 and 9611

Route 96 IN EFF:
MONDAY THRU FRIDAY

Part 2

NORTHBOUND SOUTHBOUND

BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
9610			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14		15:23	9610	
9603		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30	15:35	9603	
9608			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44		15:58	9608	
9602		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00	16:05	9602	
9611	15:23								15:33	15:44	15:52	16:03	16:15		16:23	9611	
9605			14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28	16:30	9605	
9609		15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39		16:41	9609	
9610			15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52	16:55	9610	
9603		15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05		17:08	9603	
	16:19								16:29	16:41	16:50	17:02		17:15	17:17		
9612	15:43			15:58	16:09	16:16	16:26		16:37	16:49	16:58	17:10	17:22		17:17	9612	
9608			15:58	16:08	16:19	16:26	16:36		16:45	16:57	17:06	17:18		17:31	17:40	9608	
9602		16:05		16:18	16:29	16:36	16:46		16:53	17:05	17:14	17:26	17:38		17:53	9602	
	16:11			16:26	16:38	16:46	16:57		17:01	17:13	17:22	17:34		17:47			18:07
9611			16:23	16:34	16:46	16:54	17:05		17:09	17:21	17:30	17:42	17:54			9611	18:14
9605		16:30		16:44	16:56	17:04	17:15		17:17	17:29	17:38	17:50		18:03	18:35	9605	
			16:41	16:52	17:04	17:12	17:23		17:25	17:37	17:46	17:58	18:10		18:23		
	16:45			17:00	17:12	17:20	17:31		17:35	17:46	17:54	18:05		18:17	18:35		
		16:55		17:09	17:21	17:29	17:40		17:45	17:56	18:04	18:15	18:26				18:46
			17:08	17:19	17:31	17:39	17:50		17:55	18:06	18:14	18:25		18:37			18:57
		17:17		17:31	17:43	17:51	18:02		18:07	18:18	18:26	18:37	18:48		18:53		
			17:28	17:39	17:51	17:59	18:10		18:20	18:31	18:39	18:50		19:02	19:05		
		17:40		17:53	18:03	18:10	18:19										18:29
			17:53	18:03	18:13	18:20	18:29		18:35	18:46	18:54	19:05	19:16		19:23		
		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:16		19:27	19:35		
			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:31	19:41		19:53		
9605		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:51		20:02	20:06	9605	
			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:11	20:21		20:28		
		19:05		19:18	19:28	19:35	19:44										19:54
			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:31		20:42	20:46		
		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:51	21:01		21:08		
			19:53	20:03	20:12	20:19	20:26										20:36
9605		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:11		21:22	21:26	9605	
			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48		
		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06		
			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28		
9605		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46	9605	
			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08		
		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26		
			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48		
9605		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06	9605	
			23:08	23:18	23:26	23:32	23:39										23:49
		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36			0:56
			23:48	23:58	0:06	0:12	0:19										0:29
9605		0:06		0:18	0:26	0:32	0:39									9605	0:49

Make the revisions to block 9605 to pull in after arriving at Wishram at 18:03, and then complete the blocking for the all-day blocks. The results are shown below.

SCHEDULE SHEET with revision to block 9605 and completion of all-day blocks

Route 96 IN EFF:
MONDAY THRU FRIDAY

Part 2

NORTHBOUND									SOUTHBOUND								
BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	NEXT TRIP	BLK	IN GAR
9610			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14		15:23	9610	
9603		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30	15:35	9603	
9608			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44		15:58	9608	
9602		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00	16:05	9602	
9611	15:23								15:33	15:44	15:52	16:03	16:15		16:23	9611	
9605			14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28	16:30	9605	
9609		15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39		16:41	9609	
9610			15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52	16:55	9610	
9603		15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05		17:08	9603	
	16:19								16:29	16:41	16:50	17:02		17:15	17:17		
9612	15:43			15:58	16:09	16:16	16:26		16:37	16:49	16:58	17:10	17:22		17:17	9612	
9608			15:58	16:08	16:19	16:26	16:36		16:45	16:57	17:06	17:18		17:31	17:40	9608	
9602		16:05		16:18	16:29	16:36	16:46		16:53	17:05	17:14	17:26	17:38		17:53	9602	
	16:11			16:26	16:38	16:46	16:57		17:01	17:13	17:22	17:34		17:47			18:07
9611			16:23	16:34	16:46	16:54	17:05		17:09	17:21	17:30	17:42	17:54			9611	18:14
9605		16:30		16:44	16:56	17:04	17:15		17:17	17:29	17:38	17:50		18:03		9605	18:23
9609			16:41	16:52	17:04	17:12	17:23		17:25	17:37	17:46	17:58	18:10		18:23	9609	
	16:45			17:00	17:12	17:20	17:31		17:35	17:46	17:54	18:05		18:17	18:35		
9610		16:55		17:09	17:21	17:29	17:40		17:45	17:56	18:04	18:15	18:26			9610	18:46
9603			17:08	17:19	17:31	17:39	17:50		17:55	18:06	18:14	18:25		18:37		9603	18:57
		17:17		17:31	17:43	17:51	18:02		18:07	18:18	18:26	18:37	18:48		18:53		
			17:28	17:39	17:51	17:59	18:10		18:20	18:31	18:39	18:50		19:02	19:05		
9608		17:40		17:53	18:03	18:10	18:19									9608	18:29
9602			17:53	18:03	18:13	18:20	18:29		18:35	18:46	18:54	19:05	19:16		19:23	9602	
		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:16		19:27	19:35		
9609			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:31	19:41		19:53	9609	
		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:51		20:02	20:06		
			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:11	20:21		20:28		
		19:05		19:18	19:28	19:35	19:44										19:54
9602			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:31		20:42	20:46	9602	
		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:51	21:01		21:08		
9609			19:53	20:03	20:12	20:19	20:26									9609	20:36
		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:11		21:22	21:26		
			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48		
9602		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06	9602	
			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28		
		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46		
			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08		
9602		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26	9602	
			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48		
		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06		
			23:08	23:18	23:26	23:32	23:39										23:49
9602		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36		9602	0:56
			23:48	23:58	0:06	0:12	0:19										0:29
		0:06		0:18	0:26	0:32	0:39										0:49

Finally, finish blocking the PM-only blocks. Recall that the numbering scheme in this example is by pull-out time, so block 9612 is correctly numbered. Block 9613 is the pull-out at 16:11, block 9614 at 16:19, and block 9615 at 16:45. The PM blocks are highlighted in the final PM schedule sheet below.

SCHEDULE SHEET with PM blocks added

Route 96 IN EFF:
MONDAY THRU FRIDAY
Part 2

NORTHBOUND SOUTHBOUND

BLK	OUT GAR	Libby Wshrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wshrm	NEXT TRIP	BLK	IN GAR
9610			13:53	14:03	14:14	14:21	14:31		14:35	14:45	14:52	15:03	15:14		15:23	9610	
9603		14:05		14:18	14:29	14:36	14:46		14:50	15:00	15:07	15:18		15:30	15:35	9603	
9608			14:23	14:33	14:44	14:51	15:01		15:05	15:15	15:22	15:33	15:44		15:58	9608	
9602		14:35		14:48	14:59	15:06	15:16		15:20	15:30	15:37	15:48		16:00	16:05	9602	
9611	15:23								15:33	15:44	15:52	16:03	16:15		16:23	9611	
9605			14:53	15:03	15:14	15:21	15:31		15:45	15:56	16:04	16:15		16:28	16:30	9605	
9609		15:05		15:18	15:29	15:36	15:46		15:57	16:08	16:16	16:27	16:39		16:41	9609	
9610			15:23	15:33	15:44	15:51	16:01		16:09	16:20	16:28	16:39		16:52	16:55	9610	
9603		15:35		15:48	15:59	16:06	16:16		16:20	16:32	16:41	16:53	17:05		17:08	9603	
9614	16:19								16:29	16:41	16:50	17:02		17:15	17:17	9614	
9612	15:43			15:58	16:09	16:16	16:26		16:37	16:49	16:58	17:10	17:22		17:28	9612	
9608			15:58	16:08	16:19	16:26	16:36		16:45	16:57	17:06	17:18		17:31	17:40	9608	
9602		16:05		16:18	16:29	16:36	16:46		16:53	17:05	17:14	17:26	17:38		17:53	9602	
9613	16:11			16:26	16:38	16:46	16:57		17:01	17:13	17:22	17:34		17:47	18:05	9613	
9611			16:23	16:34	16:46	16:54	17:05		17:09	17:21	17:30	17:42	17:54			9611	18:14
9605		16:30		16:44	16:56	17:04	17:15		17:17	17:29	17:38	17:50		18:03		9605	18:23
9609			16:41	16:52	17:04	17:12	17:23		17:25	17:37	17:46	17:58	18:10		18:23	9609	
9615	16:45			17:00	17:12	17:20	17:31		17:35	17:46	17:54	18:05		18:17	18:35	9615	
9610		16:55		17:09	17:21	17:29	17:40		17:45	17:56	18:04	18:15	18:26			9610	18:46
9603			17:08	17:19	17:31	17:39	17:50		17:55	18:06	18:14	18:25		18:37		9603	18:57
9614		17:17		17:31	17:43	17:51	18:02		18:07	18:18	18:26	18:37	18:48		18:53	9614	
9612			17:28	17:39	17:51	17:59	18:10		18:20	18:31	18:39	18:50		19:02	19:05	9612	
9608		17:40		17:53	18:03	18:10	18:19									9608	18:29
9602			17:53	18:03	18:13	18:20	18:29		18:35	18:46	18:54	19:05	19:16		19:23	9602	
9613		18:05		18:18	18:28	18:35	18:44		18:50	18:59	19:06	19:16		19:27	19:35	9613	
9609			18:23	18:33	18:43	18:50	18:59		19:05	19:14	19:21	19:31	19:41		19:53	9609	
9615		18:35		18:48	18:58	19:05	19:14		19:25	19:34	19:41	19:51		20:02	20:06	9615	
9614			18:53	19:03	19:13	19:20	19:29		19:45	19:54	20:01	20:11	20:21		20:28	9614	
9612		19:05		19:18	19:28	19:35	19:44									9612	19:54
9602			19:23	19:33	19:43	19:50	19:59		20:05	20:14	20:21	20:31		20:42	20:46	9602	
9613		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:51	21:01		21:08	9613	
9609			19:53	20:03	20:12	20:19	20:26									9609	20:36
9615		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:11		21:22	21:26	9615	
9614			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48	9614	
9602		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06	9602	
9613			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28	9613	
9615		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46	9615	
9614			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08	9614	
9602		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26	9602	
9613			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48	9613	
9615		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06	9615	
9614			23:08	23:18	23:26	23:32	23:39									9614	23:49
9602		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36		9602	0:56
9613			23:48	23:58	0:06	0:12	0:19									9613	0:29
9615		0:06		0:18	0:26	0:32	0:39									9615	

Once all the blocks are finished, re-calculate the Block Summary table and once again calculate the mileage. The new Hours and Mileage summary tables are shown below.

Hours Summary

Block	Garage Depart	Garage Arrive	Platform Hours
9601	3:45	8:57	5:12
9602	4:10	24:56	20:46
9603	4:15	18:57	14:42
9604	4:39	9:46	5:07
9605	4:55	18:23	13:28
9606	4:59	8:46	3:47
9607	6:05	9:57	3:52
9608	6:17	18:29	12:12
9609	7:05	20:36	13:31
9610	7:17	18:46	11:29
9611	15:23	18:14	2:51
9612	15:43	19:54	4:11
9613	16:11	0:29	8:18
9614	16:19	23:49	7:30
9615	16:45	0:49	7:44
Total			**134:40**

Mileage Summary

Block	96 NB Trips	96A NB Trips	96 NB Trips from Essex	96 SB Trips	96A SB Trips	Pull Trips Libby/Wishram	Pull Trips Sand Point	Pull Trips Pasco Essex	Pull Trips Rugby Circle	Mileage
9601	3			3		2				57.3
9602	11	2		12	2		1		1	215.1
9603	8	1		8	1	2				149.2
9604		3			3		2			54.0
9605	1	7		2	7	1			1	132.5
9606		2			2		2			39.6
9607	2			2		2				41.8
9608	1	7		1	6		1		1	117.3
9609	6	3		5	3	1			1	136.3
9610	1	6		1	6		2			112.8
9611		1			2		1		1	29.6
9612	1	1	1	1	1			1	1	41.1
9613	2	3	1	2	3			1	1	85.4
9614	1	4		1	4				2	78.4
9615	5		1	5				1	1	88.6
Total	**42**	**40**	**3**	**43**	**40**	**8**	**9**	**3**	**10**	**1378.7**

tripper

A short piece of work whose total time is less than that specified as constituting a full-time run. A tripper is often a piece of work in the AM or PM peak period that cannot be combined with another piece of work to form a split run because of insufficient hours, excessive swing time, or excessive spread time. Trippers are often operated by extraboard or part-time operators. Tripper can also refer to a vehicle that pulls out, makes no more than one round-trip, and pulls in.

Below is a comparison showing what these changes cost.

	Existing	Proposed	Change
No. of PM Peak Buses	9	11	+2
Platform Hours	130:37	134:40	+4:03
Platform Miles	1378.3	1341.7	+37.6

The change added the equivalent of half of an operator. Actually, it added two two-hour **trippers**, which may or may not be a problem for the runcut, depending on what the other blocks at this route's garage look like. The Block Summary Table shows that three of the five PM pull-out blocks continue to be close to eight hours in length, compared to two of those blocks that were on the original schedule. There will have to be some re-working of the runs in order to fit the new block profile, but at least one more pull-out to pull-in late run will be available with only minor changes to their times.

We review the other blocks in the Block Summary carefully to make sure the changed blocks do not set up a runcutting problem. For example, if one of the PM pull-outs stayed out to 20:00 or 21:00, forming a five-hour block with a late pull-in, it could not easily be worked into any run. This is a topic for the Chapter 5: Runcutting chapter, but is also an example of how schedulers must consider all aspects of scheduling when working on one particular problem. Block 9612 could be a problem in this regard.

One of the secrets to being a good scheduler is being willing to tinker constantly with the schedules—even when you think you are finished. In this case, examine how block 9612 might be changed. Specifically, instead of pulling in when it does, could its last trip hook with another trip, preferably from a longer all-day block? In our most recent schedule sheet above, the last trip on block 9612 arrives at Rugby Circle at 19:44 and pulls in. The next southbound trip departing from Rugby Circle is at 20:05 on block 9602. This is exactly the kind of swap we were hoping to find. Pull block 9602 in, and hook the trip arriving at 19:44 on block 9612 with the trip leaving at 20:05. The affected trips are shown below, followed by the final revised Block Sheet.

SCHEDULE SHEET with 9602-9612 swap - FINAL SHEET

Route 96 IN EFF:
MONDAY THRU FRIDAY
Part 2

NORTHBOUND									SOUTHBOUND								
BLK	OUT GAR	Libby Wishrm	Sand Point	Pasco Essex	Pasco Havre	Pasco Willis	Rugby Circle		Rugby Circle	Pasco Willis	Pasco Havre	Pasco Essex	Sand Point	Libby Wishrm	NEXT TRIP	BLK	IN GAR
9612		19:05		19:18	19:28	19:35	19:44		20:05	20:14	20:21	20:31		20:42	20:46	9612	
9602			19:23	19:33	19:43	19:50	19:59									9602	20:09
9613		19:35		19:48	19:58	20:05	20:14		20:25	20:34	20:41	20:51	21:01		21:08	9613	
9609			19:53	20:03	20:12	20:19	20:26									9609	20:36
9615		20:06		20:18	20:26	20:32	20:39		20:45	20:54	21:01	21:11		21:22	21:26	9615	
9614			20:28	20:38	20:46	20:52	20:59		21:05	21:12	21:18	21:26	21:35		21:48	9614	
9612		20:46		20:58	21:06	21:12	21:19		21:25	21:32	21:38	21:46		21:56	22:06	9612	
9613			21:08	21:18	21:26	21:32	21:39		21:45	21:52	21:58	22:06	22:15		22:28	9613	
9615		21:26		21:38	21:46	21:52	21:59		22:05	22:12	22:18	22:26		22:36	22:46	9615	
9614			21:48	21:58	22:06	22:12	22:19		22:25	22:32	22:38	22:46	22:55		23:08	9614	
9612		22:06		22:18	22:26	22:32	22:39		22:45	22:52	22:58	23:06		23:16	23:26	9612	
9613			22:28	22:38	22:46	22:52	22:59		23:05	23:12	23:18	23:26	23:35		23:48	9613	
9615		22:46		22:58	23:06	23:12	23:19		23:25	23:32	23:38	23:46		23:56	0:06	9615	
9614			23:08	23:18	23:26	23:32	23:39									9614	23:49
9612		23:26		23:38	23:46	23:52	23:59		0:05	0:12	0:18	0:26		0:36		9612	0:56
9613			23:48	23:58	0:06	0:12	0:19									9613	0:29
9615		0:06		0:18	0:26	0:32	0:39									9615	0:49

Revised Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

Northbound						Southbound				
Block #	***Pull Out***	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Depart Pasco Essex midroute***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9601	3:45	4:05			4:41	4:50		5:23	5:35	
		5:35			6:16	6:20		6:57	7:05	
		7:05			7:50	7:55		8:37		8:57
9602	4:10					4:20		4:53	5:05	
		5:05			5:46	5:50		6:27	6:45	
		6:45			7:30	7:35		8:17	8:35	
		8:35			9:16	9:22		9:59	10:05	
		10:05			10:44	10:52		11:29	11:35	
		11:35			12:14	12:22		12:59	13:05	
		13:05			13:44	13:50		14:30	14:36	
		14:35			15:16	15:20		16:00	16:05	
		16:05			16:46	16:53	17:38		17:53	
			17:53		18:29	18:35	19:16		19:23	
			19:23		19:59					20:09
9603	4:15	4:35			5:11	5:20		5:57	6:05	
		6:05			6:46	6:50		7:32	7:45	
		7:45			8:30	8:35		9:17	9:35	
		9:35			10:14	10:22		10:59	11:05	
		11:05			11:44	11:52		12:29	12:35	
		12:35			13:14	13:22		13:59	14:05	
		14:05			14:46	14:50		15:30	15:35	
		15:35			16:16	16:20	17:05		17:08	
			17:08		17:50	17:55		18:37		18:57
9604	4:39		4:59		5:31	5:35	6:12		6:19	
			6:19		6:56	7:05	7:46		7:57	
			7:57		8:40	8:45	9:26			9:46
9605	4:55					5:05	5:37		5:49	
			5:49		6:26	6:35	7:12		7:17	
			7:17		8:00	8:05	8:46		8:53	
			8:53		9:31	9:37	10:13		10:23	
			10:23		10:59	11:07	11:43		11:53	
			11:53		12:29	12:37	13:13		13:23	
			13:23		13:59	14:05	14:44		14:53	
			14:53		15:31	15:45		16:28	16:30	
		16:30			17:15	17:17		18:03		18:23

Revised Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

		Northbound				Southbound				
Block #	***Pull Out***	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Depart Pasco Essex midroute***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9606	4:59		5:19		5:56	6:05	6:42		6:57	
			6:57		7:40	7:45	8:26			8:46
9607	6:05	6:25			7:10	7:15		7:57	8:05	
		8:05			8:50	8:55		9:37		9:57
9608	6:17		6:37		7:20	7:25	8:06		8:23	
			8:23		9:02	9:07	9:48		9:53	
			9:53		10:29	10:37	11:13		11:23	
			11:23		11:59	12:07	12:43		12:53	
			12:53		13:29	13:35	14:13		14:23	
			14:23		15:01	15:05	15:44		15:58	
			15:58		16:36	16:45		17:31	17:40	
		17:40			18:19					18:29
9609	7:05	7:25			8:10	8:15		8:57	9:05	
		9:05			9:44	9:52		10:29	10:35	
		10:35			11:14	11:22		11:59	12:05	
		12:05			12:44	12:52		13:29	13:35	
		13:35			14:16	14:20		15:00	15:05	
		15:05			15:46	15:57	16:39		16:41	
			16:41		17:23	17:25	18:10		18:23	
			18:23		18:59	19:05	19:41		19:53	
			19:53		20:26					20:36
9610	7:17		7:37		8:20	8:25	9:06		9:23	
			9:23		9:59	10:07	10:43		10:53	
			10:53		11:29	11:37	12:13		12:23	
			12:23		12:59	13:07	13:43		13:53	
			13:53		14:31	14:35	15:14		15:23	
			15:23		16:01	16:09		16:52	16:55	
		16:55			17:40	17:45	18:26			18:46

Revised Blocking Sheet - Multiple Terminals

ROUTE 96
DAY Weekday
DATE 15-Sep-07

Special Instructions:
Goal: 7-9 minutes minimum layover time per round trip
7 minutes OK before 5:00/after 19:45

Northbound						Southbound				
Block #	***Pull Out***	***Depart Libby Wishram NB1***	***Depart Sand Point NB2***	***Depart Pasco Essex midroute***	***Arrive Rugby Circle***	***Depart Rugby Circle***	***Arrive Sand Point SB2***	***Arrive Libby Wishram SB1***	***Available for next trip (arrival + layover)***	***Pull In***
9611	15:23					15:33	16:15		16:23	
			16:23		17:05	17:09	17:54			18:14
9612	15:43			15:58	16:26	16:37	17:22		17:28	
			17:28		18:10	18:20		19:02	19:05	
		19:05			19:44	20:05		20:42	20:46	
		20:46			21:19	21:25		21:56	22:06	
		22:06			22:39	22:45		23:16	23:26	
		23:26			23:59	0:05		0:36		0:56
9613	16:11			16:26	16:57	17:01		17:47	18:05	
		18:05			18:44	18:50		19:27	19:35	
		19:35			20:14	20:25	21:01		21:08	
			21:08		21:39	21:45	22:15		22:28	
			22:28		22:59	23:05	23:35		23:48	
			23:48		0:19					0:29
9614	16:19					16:29		17:15	17:17	
		17:17			18:02	18:07	18:48		18:53	
			18:53		19:29	19:45	20:21		20:28	
			20:28		20:59	21:05	21:35		21:48	
			21:48		22:19	22:25	22:55		23:08	
			23:08		23:39					23:49
9615	16:45			17:00	17:31	17:35		18:17	18:35	
		18:35			19:14	19:25		20:02	20:06	
		20:06			20:39	20:45		21:22	21:26	
		21:26			21:59	22:05		22:36	22:46	
		22:46			23:19	23:25		23:56	0:06	
		0:06			0:39					0:49

Once all the blocks are finished, recalculate the Block Summary table and the mileage. The final Hours and Mileage summary tables are shown below.

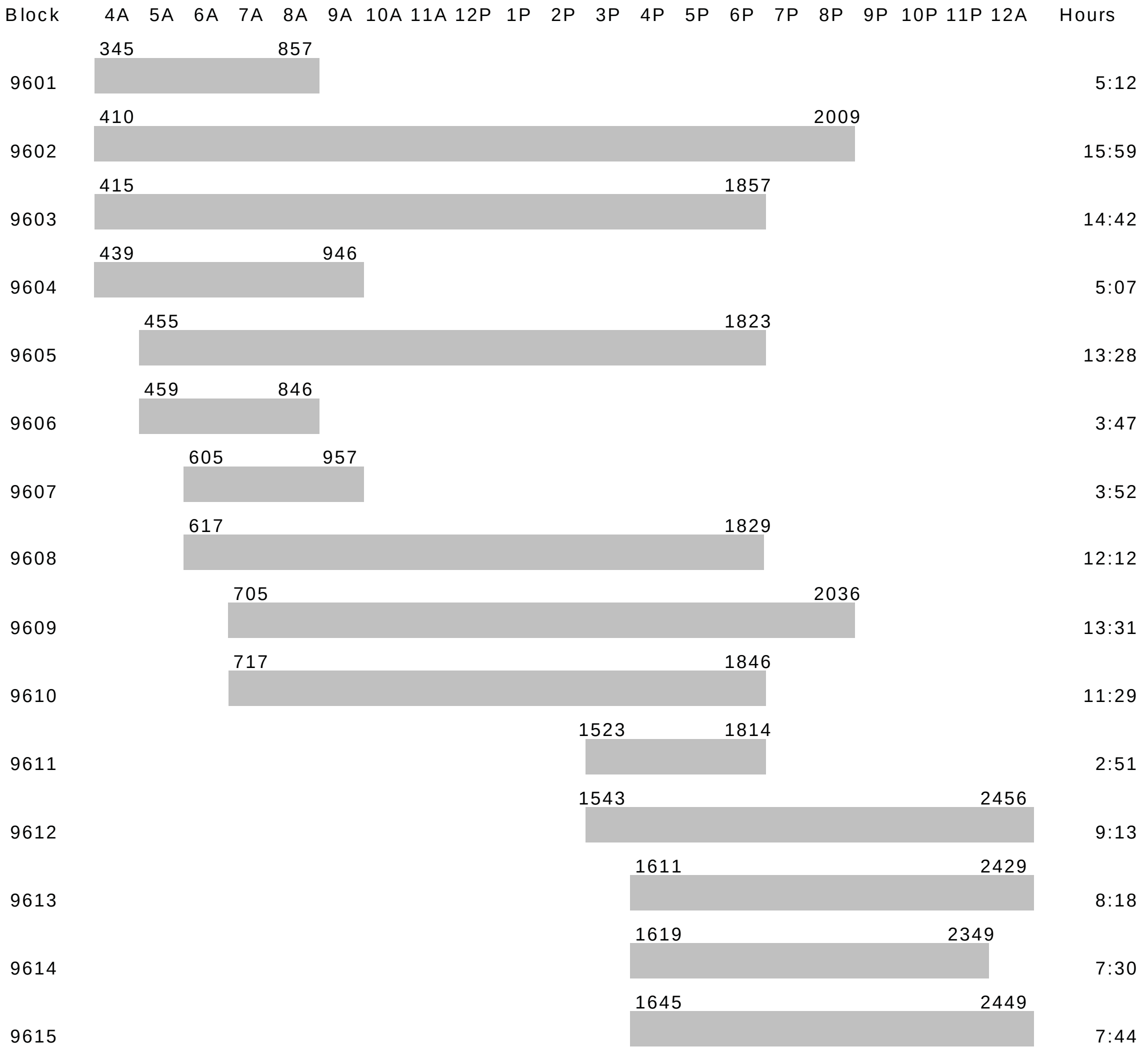
Final Hours Summary

Block	Garage Depart	Garage Arrive	Platform Hours
9601	3:45	8:57	5:12
9602	4:10	20:09	15:59
9603	4:15	18:57	14:42
9604	4:39	9:46	5:07
9605	4:55	18:23	13:28
9606	4:59	8:46	3:47
9607	6:05	9:57	3:52
9608	6:17	18:29	12:12
9609	7:05	20:36	13:31
9610	7:17	18:46	11:29
9611	15:23	18:14	2:51
9612	15:43	0:56	9:13
9613	16:11	0:29	8:18
9614	16:19	23:49	7:30
9615	16:45	0:49	7:44
Total			**134:55**

Final Mileage Summary

Block	96 NB Trips	96A NB Trips	96 NB Trips from Essex	96 SB Trips	96A SB Trips	Pull Trips Libby/Wishram	Pull Trips Sand Point	Pull Trips Pasco Essex	Pull Trips Rugby Circle	Mileage
9601	3			3		2				57.3
9602	8	2		8	2				2	157.9
9603	8	1		8	1	2				149.2
9604		3			3		2			54.0
9605	1	7		2	7	1			1	132.5
9606		2			2		2			39.6
9607	2			2		2				41.8
9608	1	7		1	6		1		1	117.3
9609	6	3		5	3	1			1	136.3
9610	1	6		1	6		2			112.8
9611		1			2		1		1	29.6
9612	4	1	1	5	1		1	1		98.3
9613	2	3	1	2	3			1	1	85.4
9614	1	4		1	4				2	78.4
9615	5		1	5				1	1	88.6
Total	**42**	**40**	**3**	**43**	**40**	**8**	**9**	**3**	**10**	**1378.7**

The change has added 0:15 to the total platform hours (134:40 before the 9602-9612 swap, 134:55 now), which results in a total increase of 4:18 from the existing schedule before the running time and headway adjustments. This should result in a more efficient runcut. The new block graph is shown below.



Observations on the advanced blocking exercise include:

- When running times or headways change, you can expect to reblock all trips after the first changes go into effect. In this case, all blocks (with the exception of the AM-only blocks) changed as a result of changed running times and headways in the PM peak.
- Each element of the scheduling process affects other elements. Consideration of the effects of blocking on runcutting can result in changes, as seen in this example. This is an important point that can get lost in the process of breaking down "scheduling" into its components, as this manual necessarily does. Good schedulers always keep this point in mind.
- Computerized scheduling software packages simplify the blocking process (and all aspects of scheduling) greatly. This raises an obvious question: why go through these spreadsheet-based exercises at all if the computer can spit out the answer I need?

  There are many levels on which this question may be answered, from the basic computer axiom of Garbage In, Garbage Out to a sophisticated discussion of the algorithms used in scheduling packages. Here is the best answer: to be a scheduler, you need to think like a scheduler and to understand all aspects of the craft of scheduling. In using computerized packages, thinking like a scheduler helps you to see where criteria can be adjusted. In this case, you could specify that no block shorter than five hours can pull out after 15:00.

  Experimenting with various criteria is one way to maximize the usefulness of a computerized software package. To do this effectively, though, you need to have a sense of which "tweaks" are most helpful. Working through spreadsheet-based or even by-hand scheduling exercises is a time-tested means of developing this sense.

Applying Garages to Each Block

In medium to large systems where routes travel a great distance and are through-routed from one side of town to the other, many routes work out of two (or more) garages. This can occur due to the size of the route in terms of the large number of buses and can also be done to minimize to the extent possible the amount of deadhead miles and hours involved with pulling out and in.

Assume that you are scheduling a through-route operated from two garages, one at each end of the route. The task for the scheduler is to get the respective blocks back to their home garages while minimizing operator pay hours. In the simplest example, buses pull out to either end of the route or to a midpoint such as downtown. As seen earlier, blocks do not necessarily end service at the same location where they begin service. Following normal blocking practice as discussed earlier, blocks will naturally end at (1) the same place of the route where they began, (2) at downtown, or (3) at the opposite end of the route. The goal is to eliminate as many of these "end opposites" as possible, or more formally, to minimize the number of runs that end in places that require long deadhead trips to reach the garage.

There is no miracle way of making blocks end where they began. The scheduler deals with each block individually. The same-side start and finish blocks are checked off and forgotten about. Normally downtown starts or finishes are a "free square" which offers half the savings (half the deadhead of going from one side of the route to the other to pull in). The scheduler can check those off too, since there is no perfect solution and downtown is a legitimate place to start and end service. That leaves us with the "end opposite" blocks. There are only two potential actions for fixing these: (1) re-hooking or (2) creating extra trips.

We discussed re-hooking in order to give us a better block length to aid the runcutting process. In the case of a long, through-routed line, we could also re-hook trips to yield a block which starts and finishes on the same side of the route. Care must be taken, though, that re-hooking works for both blocks involved. The resulting change must work for both. The concern of leaving a block that becomes a runcutting problem must also be considered. If the scheduler has to choose between the lesser of these two "evils" it is usually best to go with block length. That is probably the least expensive choice, as deadhead time and miles may well be less costly than a block whose pieces wind up as trippers.

Creating extra trips may be desirable if they come at a time where ridership would benefit from them. Schedulers normally view any trips that are above what is needed to meet the standards for carrying passenger volume as "bad." In this instance, however, the added trips may not add all that much extra cost, since the mileage has to be operated anyway and the extra time in service over and above that required for deadheading may yield extra patronage. This is where the scheduler's good judgment comes into play.

Midday Storage Lots

A number of larger systems store buses during the day at a central location, usually near downtown. These central storage facilities may be as simple as a parking lot located under an elevated portion of a freeway or may be a dedicated lot with covered parking and full facilities for drivers and supervisors, including a waiting lounge. Sometimes a centrally located bus garage can be used to host these "foreign" blocks during the midday.

This arrangement is especially handy for saving unnecessary deadheading of equipment and operators. The agencies that use central midday storage normally have suburban or interurban routes that operate from quite a distance out and would have a relatively long return back to their respective garages. Many of these routes are peak-direction-only express routes that require lengthy deadheads to pull in after the AM peak and to pull out before the PM peak.

In most cases, these agencies have negotiated with their unions to eliminate the need to pay drivers to deadhead back to the garage, so there is a significant saving in both miles and platform hours. However, most systems do provide transportation back for those who want to return to the home garage. This is typically handled by sending selected pull-ins through the storage facility every 30 to 60 minutes to pick up any drivers wanting to go back. The process is reversed for the start of the PM peak. In cases where the labor agreement requires payment to drivers, the shuttles between the garage and the storage lot can be more frequent, on the order of every 10 to 15 minutes.

The scheduler's responsibility here is to pick candidate blocks from the various routes and garages which would benefit from this scheme. Several garages may be involved, but constrained parking space is often the limiting factor (the union contract may also specify a maximum number of buses that can be stored). Besides picking out the blocks which would stay, the scheduler must also arrange a schedule of buses going back to the home garage from the pull-ins available. There is an obvious need to account for all of the storage buses to make sure that they are all needed to pull out for the PM, although they could be used on a different route ultimately returning to the home garage.

Interlining on a Garage or System Basis

Modern block optimizing software has given the scheduler the ability to throw a large garage's worth of blocks or a sector of a system into an electronic hopper and allow the software to try to reduce the number of blocks necessary to operate a given set of trips by looking system-wide or garage-wide at all interlining possibilities. The software adds a new dimension to the task by asking if certain key trips during peak times, when the number of buses is at a premium, can be moved by one or more minutes in order to effect a bus saving. One large transit system saved well over a dozen buses during the AM peak using this software in one sector of their service area. This resulted in monetary savings, but also in extensive deadheading between terminals on different routes in order to achieve the savings. Operators also found themselves working a number of different routes during the course of their day.

The upsides of using these block optimizers are obvious:

- The savings in peak buses can be significant
- The peak bus savings translates directly into run and operator reduction

But, there are downsides also:

- The scheduler must know when and where to use this tool or what we will characterize as needless interlining will occur. Remember that the computer does not “see” the movement of buses; it only accounts for the mathematical savings. This can result in some unexpected situations, such as two buses passing each other while deadheading to each other’s former route in order to shave a couple of minutes off vehicle hours. This is particularly true during off-peak periods where headways are generally stable and random interlines would not normally be considered as a way of saving hours.
- The travel time information in the point-to-point deadhead table that drives the optimization must be accurate and kept up-to-date. Otherwise, delays are spread to a number of routes, decreasing the overall on-time performance. Maintaining this large matrix is not a simple task. APC or AVL information needs to be available in large quantity and to be monitored regularly.
- The transit agency must use a scheduling package that offers the block optimizing routine as an extra cost add-on. Not all packages have this routine. To perform this kind of global optimization by hand is incredibly time-consuming and usually beyond what time is available to the scheduler to prepare for the next sign-up even without this extra step.

The recommendation is that schedulers should always look to their knowledge of the route structure and route performance information before deciding on how to set the criteria guiding the block optimization software. Interlining stray peak-hour pieces is a rightful concern for the scheduler, but it is possible to go overboard with the block optimization tool. Common sense and knowledge of your system can guide you.

alternate-fuel buses

Buses using low-polluting fuels in place of diesel or gasoline. Examples of alternate fuels include compressed natural gas (CNG), liquefied natural gas (LNG), ethanol, methanol, and propane. Electric or hybrid electric vehicles also fall within this definition.

articulated bus

An extra-long (54 to 62 feet) bus with the rear body section connected to the main body by a joint mechanism which allows the vehicle to bend when in operation for sharp turns and curves and yet have a continuous interior for passenger movement.

Route Assignments by Garage

Many transit agencies periodically revisit which bus routes are assigned to which garages. Ongoing scheduling changes that add or reduce the number of buses operated on each route may conflict with the capacity of a particular garage. Introduction of new types of vehicles (**alternate-fuel, articulated buses**) for use on specific routes may result in reassignment of those routes to garages with the capacity to store and/or fuel these vehicles. Opening a new garage usually triggers an analysis of this type.

The scheduler’s goal in route assignment is to minimize deadhead miles and hours within any system constraints (garage capacity, fueling capabilities, maintenance bays that can accommodate articulated buses). Computerized scheduling software is very useful in this task, particularly for major changes such as the opening or closing of a garage.

A reconsideration of route assignments by garage does not need to be done more than once every five years or so—even less often if service levels are stable. The scheduling survey revealed that this is a common but not a universal practice among agencies that operate out of multiple garages.

LEVEL 3

End of Schedule Blocking.

Runcutting continues on the next page.

Chapter 5.
Runcutting

5.1 Basic Runcutting

LEVEL 1

Runcutting is the process of turning **blocks** into work pieces or "**runs"** for drivers. The word cutting is used to describe the process of "cutting" blocks into pieces that drivers can actually work. A "run" may consist of all or part of a vehicle block, and may have single or multiple pieces. During the runcutting process blocks may remain intact, be cut, or in some cases be completely rehooked.

In practice runcutting is an extremely complex process that takes into account a range of factors, both qualitative and quantitative, to produce a set of outcomes that significantly affect transit operations and an agency's budget. The scheduler is actually creating the work days for the bulk of the agency employees, significantly affecting the cost of operation. The schedules department is in many ways a transit agency's budget implementation and enforcement department.

We should note up front that runcutting can range from simple solutions to infinitely complex problems. In fact, most computerized runcut "optimizers" are not true optimizers at all—they cut down the problem into something manageable and then optimize that solution. This shows just how complex the mathematics of runcutting can be—that even the most powerful computers are not able to mathematically solve complex runcutting problems.

Runcutting Objectives

What are we trying to achieve when creating runcut solutions? There can be many objectives, and defining the objectives can be an extremely difficult task, raising more questions than it answers. But knowing the priorities at your agency is critical because without objectives one cannot measure the success of a runcut. Below we note some of the typical objectives a scheduler will be trying to achieve when undertaking runcutting.

1. **"Legal" Solutions.** First and foremost the runcut must be "legal." This is an expression used at many systems and because labor contracts are often involved, indeed there are times when it carries the force of law. "Legal" means that it must meet all the written rules of the labor agreement. It must also meet any safety, driving time, or break requirements, some or all of which may be legislated.
2. **Efficient Solutions.** In most cases the scheduler will be trying to achieve an efficient runcutting solution. In bus transit agencies the operator cost typically accounts for more than 50% of total operating cost. Therefore the impact of runcutting efficiency is significant in overall operating efficiencies. Exactly what defines "efficiency" can at

runcutting

The process of converting (or cutting) vehicle blocks into work assignments for operators.

run

A work assignment for an operator. Most often, run refers to a whole day's work assignment.

block

A vehicle (or train) assignment that includes the series of trips operated by each vehicle from the time it pulls out to the time it pulls in. A complete block includes a pull-out trip from the garage followed by one or (usually) more revenue trips and concluding with a pull-in trip back to the garage.

rehooking

The process of changing how trips are linked into a block. This is done when evaluating blocks and during the runcutting process.

Tip The word "run" is often misused. Individual trips, nonstop portions of routes are often called "runs" by laymen. Do not stray from the appropriate definition and use.

times be somewhat difficult to determine and will be discussed in some detail in the following sections.

3. **"Streetable" Solutions.** The scheduler should create runcuts that maximize the operational potential of the solution. For the same cost and legality, comparative runcuts could diminish (or alternately enhance) the ease of operation. For example, in systems which have relatively high "leave" benefits, i.e., vacation days, personal days, sick days, birthdays off, etc., a streetable solution might mean more runs markedly longer than 8 hours, often in the 9- to 10-hour range (5-day work week).
4. **"Friendly" Solutions.** In addition to the above objectives the scheduler should be trying to achieve results that allow for a "reasonable" workplace for the operators. Schedulers need to be aware that the runs and rosters developed define an operator's entire work life, and should look to achieve a balance of operator requests and preferences where possible.

Of course some of the above objectives are at times in conflict or at the very least difficult to achieve simultaneously. That is where the skill of the scheduler, able to balance the varying objectives, comes into play.

Types of Runs

Runcutting, as described above, is creation of operator assignments or runs. But what are these runs? The **types of runs** operated by public transit agencies generally fall into three broad categories. These are described below.

1. **Straight Runs.** This type of run implies work paid as "straight through" or continuous time on duty. Traditionally a straight run has consisted of a single piece of work, where the operator stays on the same vehicle for the whole day. A second type of straight run involves a break (often required by labor agreement or legislation) between two pieces of work. This break may be paid or unpaid, and be taken on the vehicle or at the depot, according to site-specific labor agreement provisions.[1] The break in a straight run is often between 30 and 60 minutes in duration.

   Below are graphical examples of straight runs.

straight run

A run in which trips are consecutive without interruption. Straight runs do not contain any breaks (except for meal breaks at some systems) for the operator. Any break in a straight run is usually less than one hour in length. A straight run with a break is referred to as a multipiece straight.

split run

A run containing two or more pieces of work separated by a break over one hour in length. Also known as a swing run. At some systems, three-piece split runs are allowed, but one of the breaks (or "swings") is usually paid whereas in two-piece split runs the break is generally not paid. Split runs tend to be used to allow both peaks to be covered by one operator since the work day would otherwise be too long for a straight run.

swing time

The elapsed time (usually unpaid) between the pieces of a split run. Also known as "intervening time." if swing time is paid, it is sometimes called "inside time."

spread time

Total time between the start of the first piece and the end of the last piece of a split run with two or more pieces. Also known as "outside time."

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[1] In some systems with both types of these straight runs, only the former is called a "straight," the latter, even with a break under 60 minutes, is considered at that system to be a split (or swing). For simplicity, this document distinguishes them as one-piece straights and multipiece straights.

2. **Split Runs.** Split (or Swing) runs refer to runs that have two pieces, with a (usually) longer unpaid break between those pieces. The operator is not on duty between the pieces of work, and typically all pieces start and finish at the home garage. The break in a split run is characteristically longer than for straight runs (both kinds), greater than 90 minutes, and may be as long as three or four hours. Split runs tend to be used to allow both peaks to be covered by one operator since the work day would otherwise be too long for a straight run.

   Below is a graphical example of a typical split run.

3. **Trippers.** Trippers are almost always short one-piece straight runs, and are often used in peak periods. Trippers are sometimes known as "part-time runs."

   In some cases the difference between types of runs can become fuzzy—particularly between a split run and a straight run with an unpaid break, or between a tripper with multiple pieces and a split run. Invariably, though, the unique conditions identifying each run type can be found in your labor agreement (and it is likely that your agreement clarifies the differences between very similar runs).

These examples are basic in nature and do not cover all types of runs or all types of applications of those runs. For example, a split run does not necessarily cover both peaks, and in fact may be used on weekends or where there is little peak effect.

Components of Runs

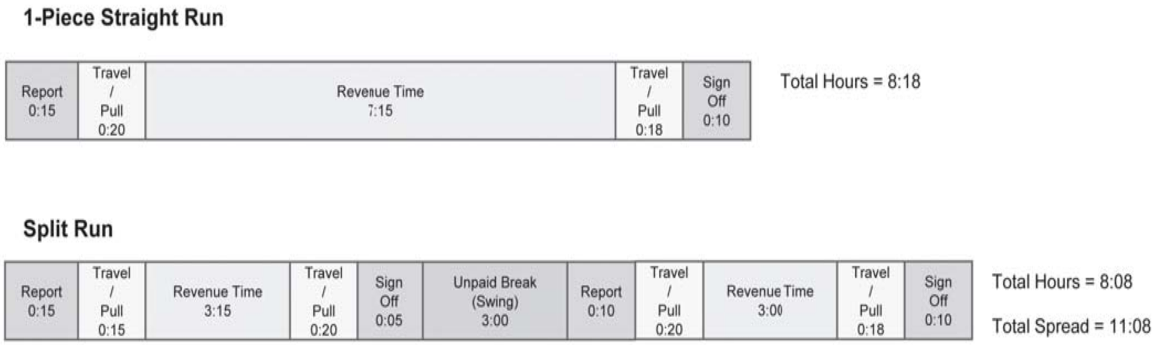
Runs consist of a number of distinct components—the actual in-vehicle time is only one of them. Importantly, the actual driving time is only one of several components and may account for as little as 60% or 70% of the total paid time, depending upon the type of run and labor agreement provisions.

tripper

A short piece of work whose total time is less than that specified as constituting a full-time run. A tripper is often a piece of work in the AM or PM peak period that cannot be combined with another piece of work to form a split run because of insufficient hours, excessive swing time, or excessive spread time. Trippers are often operated by extraboard or part-time operators. Tripper can also refer to a vehicle that pulls out, makes no more than one round-trip, and pulls in.

Tip There are many different issues to juggle when developing split runs. Before you begin, know whether your property has rules regarding the total length of the driving day including the unpaid break times, the length of time a driver can drive, whether runs with more than two work pieces are allowed, i.e., three-piece runs, and the trade-offs between split runs and trippers.

The diagram below provides a graphic visualization of the possible components of a run. It is interesting to note than in the split run shown the actual driving time is responsible for only two of eleven unique run components.



Total **work hours** and spread hours are indicated as these are numbers that are needed to calculate penalties such as **overtime, spread**, and **shift premiums**. These penalties or premiums—which in some systems are collectively known as **"collaterals"**—are discussed in more detail in later sections. At this stage it is sufficient to note that understanding the components of runs is required to develop an understanding of the runcutting process.

Runcutting Outputs

The outputs of any scheduling process can be broken down into two categories—the actual operational outcomes, and the reports required describing those outcomes.

In the case of runcutting the outcomes are simply a set of operator assignments that are valid, cover all of the blocks, and meet the objectives of the agency. However there are work units, i.e., departments, divisions, offices, etc., of an organization that require a description or summary of those runs—in effect, the tools with which certain people will be able to undertake their roles. Some of these are listed in the table below.

work hours

Total hours worked by an operator, not including fringe benefit hours such as sick leave, holiday, etc. Work hours include only labor hours associated with the requirements of putting the runs in service and operating the service.

collaterals

All of the various types of penalties and premiums that might be required to make legal runs.

premium pay

Pay to an operator that is over and above the straight time pay rate; includes overtime premium, spread premium, shift premium, and any other operating premiums as defined by the contract.

overtime premium

Pay at the rate of 1.5 times (or higher) the normal rate for work performed in excess of daily or weekly thresholds, usually eight or ten hours per day or 40 hours per week.

shift premium

A premium paid to operators for working during times of the day that are subject to special pay differentials, e.g., an owl (late night/early morning) run.

spread premium

Pay equal to one-half or more of all minutes in excess of a specified maximum spread time, in addition to regular straight pay. The spread premium may be multilayered, e.g., half of all time up to 60 minutes over the specified maximum spread time and three-quarters or all time more than 60 minutes over the specified maximum spread time. Spread premium is separate and distinct from overtime premium.

Output	Description	Used By
Run Guide	A summary of runs that describes start/finish locations, work hours, and cost element breakdowns	Schedulers, garage staff
Runs Summary	List of runs showing start/finish times, hours worked, and paid hours	Payroll systems
Dispatch Sheet	A list of all runs, sorted by start time	Garage staff, to track staff and vehicle movements throughout the day
Runcut Statistics	Summary of costs, totals, penalties, etc.	Schedulers for summaries/comparisons, Senior Management for costing analysis

The Role of Computers

You will recall the comment that many runcutting problems are qualitative in nature and are, therefore, too complex for any computer, alone, to optimize completely. This does not, however, mean that computers do not have a significant role to play as tools to significantly assist in developing runcuts.

Computerized Scheduling Packages

The advent of computerized scheduling packages containing complex algorithms has enabled significant improvements in the ability to generate efficient runcut solutions. However, since the computer is trying to solve what it sees as a mathematical or quantitative problem, the inputs need to be numeric. So as a scheduler you will need to resolve issues of preference in terms of weights or penalties. And this requires skill and practice. For example, do you think that longer spreads are less preferred than having additional trippers? If so, by how much—50%, 100%? The automated algorithms require the user to be able to define such preferences concisely and numerically.

The modern ability to run numerous runcut solutions and compare results is a significant benefit generated by automated runcutting programs over previous manual-only runcuts. A key point to remember is that the computer is only a tool to be used by the skilled scheduler, to produce high-quality solutions. Keeping this in mind, here are a few considerations when using computerized systems to generate runcuts:

- **Never accept the automated solution as given**. Always consider the need to fine tune—for operational preference, runcut desirability, or whatever reason. Very rarely is an automated solution ready for implementation without the need for some, even if minor, manual manipulation.

- **Run multiple solutions**, each time changing (preferably) one constraint at a time. The direct impact of this particular constraint can then be measured. Then do the same process with constraints that impact on each other. This way, the best set of inputs can be developed.
- **Experiment, review, change, and adjust**. Use the interactive tools to review and adjust solutions. This may lead you to adjusting parameters, weights, costs or constraints, and resubmitting for a complete new (and improved) solution.
- **Use the tools provided by the system to work interactively.**
- **Use the tools provided by the system to double check** accuracy of a runcut solution.
- **Familiarize yourself with *all* of the ways the system can summarize**, present, and allow you to review information.

Our experience is that users tend to focus on a subset of the available functionality of computerized systems and as a result do not exploit the full capabilities of the software. This in turn affects either the efficiency or quality of runcuts created.

Basic Spreadsheet Tools

The spreadsheet is not forgotten as a means of developing runcuts either. Spreadsheets provide a range of capabilities. Some typical examples include:

- **Calculation.** Use formulas as much as possible to calculate totals, penalties, costs and to generate summaries. For example, if the **report allowance** is 10 minutes, and you want to show both garage depart and **sign-on times**, the sign-on time field should equal the garage depart time less 10 minutes (expressed in a formula as 0.00069444 x 10 or as time(:0,:10,:0)). If the **clear allowance** is 10 minutes, then the sign-off time would equal the garage arrival time plus 10 minutes. There are endless examples, at varying levels of sophistication, where calculations can be automatically generated. In addition, times can be converted from time to decimal format if so desired. If the entry in cell A10 is 8:24, the formula is: =hour(a10)+minute(a10)/60, which yields 8.4.
- **Visualization.** Use formatting to show a variety of information. For example, use conditional formatting to show if something is not legal (e.g., if the total spread field is greater than 12 hours and the maximum allowed is 12 hours, highlight the cell with a red background). Conditional formatting in spreadsheets is a powerful tool that can greatly assist the scheduler.
- **Validation.** Use formulas to check whether rules and preferences are being broken. These can be applied as checked fields, or as formatting changes, highlighting issues.

report allowance

The amount of time paid an operator from sign-in time to pull-out time. During this time, the operator may obtain instructions and supplies pertinent to his/her run, locate the assigned vehicle, and perform a pre-trip inspection.

sign-on time

(sometimes called sign-in time)

The time an operator is assigned to report for duty at the start of each piece of a run. The operator may be required to sign in or may be acknowledged by the dispatcher as having reported.

clear allowance

The amount of time paid to an operator at the conclusion of the run to turn in transfers, fare media, or other supplies and reports.

Tip Learn the things your runcut program does best and use it to your full advantage. Not all programs are equally good at all aspects of runcutting.

pay-to-platform ratio

The ratio of pay hours to platform time. For example, if an operator receives 9:00 in pay for 8:00 of platform time, the pay-to-platform ratio is 1.125 (9:00/8:00). The pay-to-platform ratio is one of the most widely used methods of measuring runcut efficiency and is often used to measure the impacts of non-platform items (such as report or travel times) on operator pay hours. Some systems use the inverse, the ratio of platform to pay hours.

pay hours

The number of hours for which an operator is paid at his/her rate. Pay hours include work hours, make-up time, overtime premium, spread premium, and any other adjustments called for in the contract.

Tip Linking spreadsheets with "look-up" formulas minimizes direct entry and allows you to keep all of your input variables on a single master sheet.

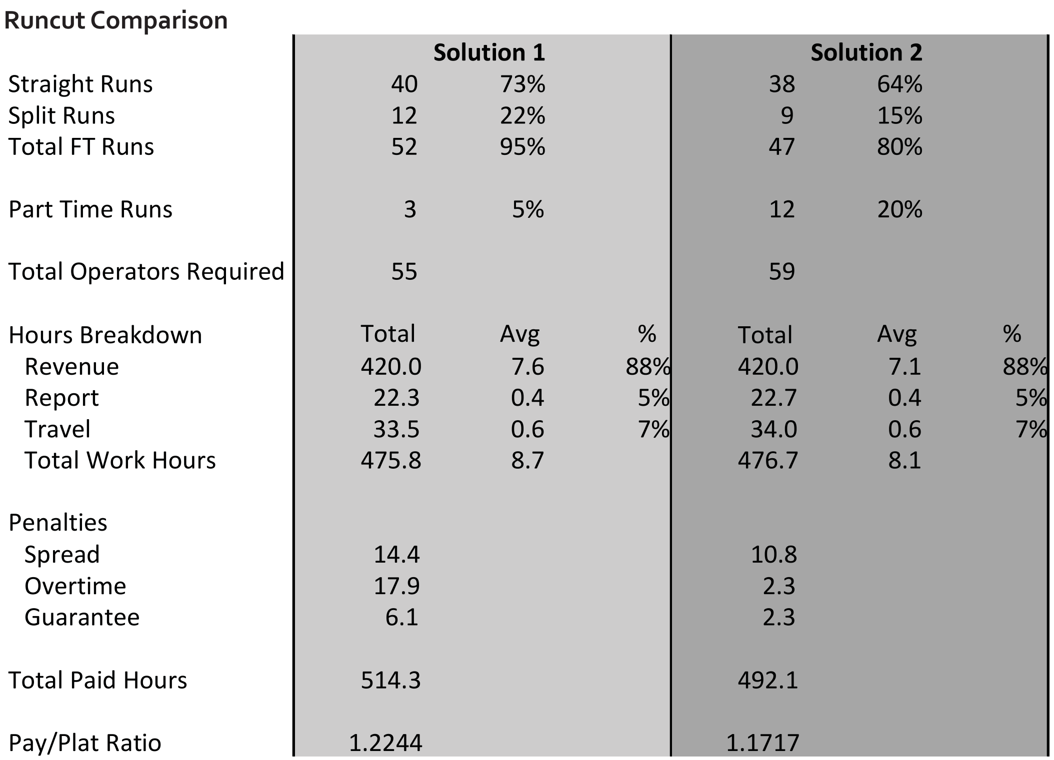
Finally, and this cannot be stressed highly enough, do not type values into cells unless absolutely necessary! The more numbers that are typed, the greater the chance for error. Use formulas, calculations, and formatting as much as possible. Learn to use lookup tables and other functions that can assist to streamline the runcutting process, and can reduce errors. As with computerized scheduling packages there is a tendency for schedulers to use only a small portion of the capacity and power of spreadsheet systems.

How to Measure the Success of a Runcut

The success of a runcut is always measured against the standards and objectives of the agency. Usually based on agency historic data as a foundation, **pay-to-platform ratios** are the primary guide (more about pay-to-platform later in this section). Some typical objectives were discussed above. As with many aspects of scheduling, be thorough and methodical. Develop a template for comparing one solution to the next (spreadsheet is preferred), each with a score or summary for the key criteria. Only when the relevant information is laid out can an objective assessment then be made.

Remember, as a scheduler you will be asked to provide advice regarding the differences or impacts from one runcut to the next. And even before you reach this point you are likely to compare your initial or preliminary solutions as you consider alternative solutions.

The example template below compares some key cost measures between two runcuts. A debate about the merits of one solution against another will be put off until later in this chapter. Suffice to say, the tables allow us to see quickly that Solution 2 uses more part-time operators but achieves a lower cost. The agency objectives and experience can then be used to determine whether that is a desirable outcome or not.



Runcut Comparison

	Solution 1			Solution 2		
Straight Runs	40	73%		38	64%	
Split Runs	12	22%		9	15%	
Total FT Runs	52	95%		47	80%	
Part Time Runs	3	5%		12	20%	
Total Operators Required	55			59		
Hours Breakdown	Total	Avg	%	Total	Avg	%
Revenue	420.0	7.6	88%	420.0	7.1	88%
Report	22.3	0.4	5%	22.7	0.4	5%
Travel	33.5	0.6	7%	34.0	0.6	7%
Total Work Hours	475.8	8.7		476.7	8.1	
Penalties						
Spread	14.4			10.8		
Overtime	17.9			2.3		
Guarantee	6.1			2.3		
Total Paid Hours	514.3			492.1		
Pay/Plat Ratio	1.2244			1.1717		

Note that total operators could potentially be shown in terms of Full-Time Equivalent (FTE) operators. In such cases part-time operators may be substituted on a 2 for 1 basis. For Solution 1 the FTE would be 53.5, and for Solution 2 the FTE would be 53, using this approach. Be careful, though, since that approach works well where part time operators are covering the peaks and have shorter average hours, but may be misleading if the part-time runs are longer or not only covering the peaks. The approach to definition of FTE, and the applicability of FTE as a measure to compare runcuts, will vary by agency. Some agencies just view each employee as part of a headcount, and some use an FTE approach.

Runcutting Inputs

The success of any runcut depends on the quality of the information available as inputs to the runcutting process. This applies as much to manual runcutting as it does to computerized runcutting. If the basic elements of a runcut are not well defined, the result will not be effective.

Tip Before beginning the runcut, take a broad view at your blocks. Understand whether the same level of service operates all day, which lends itself to straight runs, or whether service is “peaked” with more vehicles (and drivers) required during limited times of day. This lends itself to a combination of part-time and split runs in addition to a full-time and straight runs. The more variation in block sizes, the more likely you will have a complex runcut.

Tip DO NOT attempt a runcut until you know your blocks are complete and correct and all work rule preferences are defined.

travel time

Paid time allowed for an operator to travel between the garage and a relief location. If the travel is for relief purposes only and is not part of a pull-in or pull-out, then travel time is not included in platform time.

service curve

A plot of the number of buses in service by hour.

Scheduling requires absolute accuracy of details. To this end, make sure you have a good methodology for ensuring that when you start to runcut, whatever the size of the problem, you have the following pieces of information, *in their entirety:*

- A complete set of trips and vehicle blocks;
- All relevant defined rules (usually the labor agreement summarized);
- Defined relief types, relief locations, and **travel times**; and
- Known limitations—cost limits, work rule preferences, etc.

Most automated scheduling packages have a means for checking that all the required information is available to start runcutting. Always double check, though. You can simply go back and check your vehicle stats against what they should be. For spreadsheet-based methods, make sure you have a checklist, and a method for viewing both the runs and blocks details. Checklists are important throughout the scheduling process, to ensure work is undertaken thoroughly, in a methodical manner.

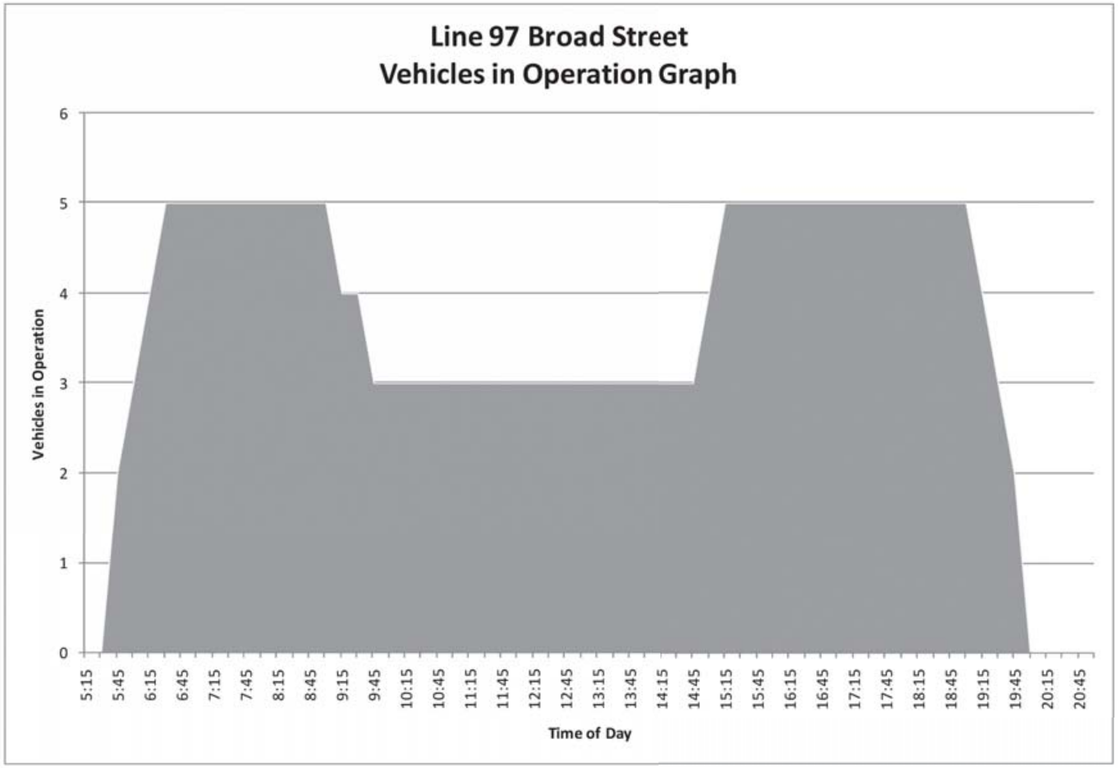
Trips/Blocks

First and foremost we need something to runcut. The runcut process starts with a complete and correct set of vehicle blocks and trips. Where blocks define the assignment for a given vehicle, the run will define the assignment of a given driver.

We can, at this stage, consider the nature of the blocks and runs we are working with. In particular the nature of the **"service curve"** can affect how we will approach the runcutting process. For example, is the service highly "peaked" (i.e., has a lot of blocks with peak-only trips), or do the same frequencies operate pretty much all day? The answer to this question will have a significant bearing on how the runcut results will look and on how we approach the runcut.

The Broad Street example will be used to show how to lay this out visually. Remember that while scheduling is a very detailed, numbers-based process, the best way to understand the data is often by looking at things visually, usually with graphs. This allows a simple representation of a great deal of detail that would otherwise be difficult to understand.

Below is a simple "Vehicles in Operation" graph. This graph simply shows how many buses are in operation anywhere at any given time during the day on Route 97 Broad Street. The graph can be generated quite simply in a spreadsheet. For computerized scheduling packages the graph can be generated automatically—so check out how to do so as this is an invaluable tool.



Looking at this graph, we can immediately see that there will be some complexity in cutting the runs during peak times. We can also assume that we may need to use different run types to cover the peaks, including (potentially) split runs or trippers.

Some other things we can immediately note in the graph above include:

- Many of the blocks are around 14 hours which will probably allow us to cut them into two pieces, each as a single run.
- The peak blocks are shorter in the AM Peak than the PM Peak (this is not unusual). The AM blocks are around 3:30 and the PM blocks around 4:30. This may allow us to create 8:00 split runs without too much difficulty (subject to spread limitations).
- We will need two additional runs during the peaks to cover the two additional peak vehicles.
- We will have three runs in operation during the off peak.

vehicles in operation graph

A graphical representation of the number of vehicles in operation by time of day, typically by route but also by garage or system.

So by simple visual representation, without looking at any tables of numbers, we can discern a great deal of information about the vehicle blocks, their impacts on the runcutting to follow, and some potential outcomes. Of course not all graphs will have this form—some have unbalanced peaks, some are flat, or have higher peaks, or wider/shorter spans. But in each case one can immediately consider implications for the runcutting process. Naturally, as we get into the actual cutting of blocks we will need to work at a more detailed level.

Rules, Constraints, and Practices

We now have a set of blocks to generate runs from. What else do we need? One thing you will hear about often when discussing runcutting is the word "constraints." In the context of creating a runcut there are numerous constraints, each limiting how we can cut the blocks into runs.

Constraints include the following types of categories:

- **Hard Rules.** "Hard" rules are typically defined in the labor contract. They include specific fixed limits such as how many hours can be worked in a day, or how many of a type of run is allowed. Sometimes hard rules are expressed as a fixed number (e.g., a 10-hour maximum work time in a day). In some cases they are expressed as percentages (e.g., no less than 20% of full-time runs may be straight runs). At times the language and definition of hard rules can be extremely complex. In this context hard rules cannot be broken and are nonnegotiable.
- **Soft Rules.** "Soft" rules may be in the labor contract or may fall into the category of "operating practices" (see below). Soft rules tend to be preferences or "wants," rather than nonnegotiable requirements. Typical soft rules tend to relate to not scheduling excessively to hard rule requirements. For example, while you may be allowed to schedule up to a 13-hour spread, there is a preference to keep as many as possible within 12 hours. This may be written into the labor agreement or may just be an understanding with operators.
- **Operating Practices.** Some constraints, both hard and soft, are not written into the labor agreement, or even necessarily required by operators, but are applied based on either historical precedents or by preference. For example, it may be an agency preference that any operator who works on a certain route always gets a break every two hours (if that is a busy route). Or perhaps, going back to the spread example, the labor agreement allows 14-hour spreads but Management sees that as excessive and prefers to schedule to a 13-hour maximum.

The labor agreement will be unique to each agency and therefore we do not propose here to prescribe what it will or will not include. We would, however, urge every scheduler to consider each constraint they are given and consider if it is:

a. required by the labor agreement;
b. in line with agency objectives;
c. in keeping with good scheduling practices; and
d. properly defined or implemented.

The table below lists some typical types of constraints or rules found in labor agreements, or in operating practices, of transit systems across the United States.

Work Rule/ Constraint	Typical Source	Notes
Minimum/Maximum Work Times	Labor contract	Can either be expressed in terms of platform time or work time.
Run Types Allowed	Labor contract	Typically will discuss straight runs, split runs, and trippers. Nearly all run types are some derivative of these.
Run Type Requirements	Labor contract	Relates to minimum or maximum allowed of specific run types.
Spread Time	Labor contract, operating practice	Maximum spread time is usually specified in the labor contract.
Meal and Break Requirements	Labor contract, operating practice, state regulations	Will dictate whether straights are one-piece or multipiece and if so, are breaks paid/unpaid, and how long/short must they be. In some states break requirements are legislated and may override the agency-specific labor agreement. Breaks may also be driven by agency preferences.
Report/Clear Allowances	Labor contract, operating practice	Typically mandate allowances at start and end of runs, and possibly around breaks. Usually expressed as time (e.g., 15 minutes report allowance at the start of a run).
Relief Requirements	Labor contract, operating practice	Labor contract may describe where and when reliefs can occur, how they must be undertaken, time allowed for travel, etc. Alternatively, may be totally based on agency operating practice, often by verbal agreement with operators. See following section for discussion of reliefs.

Computers and Constraints

It is one thing to understand a labor rule or constraint. It can be an entirely different thing to be able to succinctly define that constraint in a way that a computer can meaningfully process.

In this context we are considering two types of computers—the spreadsheet and sophisticated proprietary computerized scheduling package. For a spreadsheet we may be considering simple things such as conditional formatting to highlight where runs are longer than allowed. For a computerized system the range of input approaches varies considerably, from screens that specifically ask for minimums/maximums, to the requirement to write a line of "almost computer code" to describe a complex preference.

Consider the following rule in the labor agreement at an agency:

> *At least one of the following constraints must be met in straight runs over 8 hours:*
>
> - *1 x 20 minute break and 1 x 10 minute break; or*
> - *3 x 15 minute breaks; or*
> - *60 minutes total layover (15% of runs minimum)*

The agreement may further state that not only must one of these constraints be applied in each run, but also that 80% must be achieved in actual operation. In fact, though, all scheduled break requirements are expected to be achieved in operations. Schedules should never be knowingly written that are inoperable. Runs are further limited by the requirement that no more than 23% of runs can involve a vehicle change. This limits options to create multipiece runs to deal with the breaks.

To model this as a spreadsheet is virtually impossible, and so when the runs are created it will require a great deal of management by the scheduler. Even in an automated system there will be different ways to approach and model the rule. In this case there are a mix of hard rules, percentage limits, and preferences.

The important thing to understand is that when providing input to a computer (be it spreadsheet or automated system) the user must be able to clearly understand and describe the rule/constraint and, just as importantly, must understand the intent of the rule. Only by understanding the intent of the constraint will the user be able to control the outcome to achieve that desired result.

In most computerized systems users will be required to weight rules as the system strives for an optimal mathematical result. Understanding this is very important—the computer will be considering every aspect of the runcut as a mathematical problem, to which it is trying to provide an optimal mathematical solution. Therefore in most instances the scheduler will be required to express the rules, constraints, and preferences in terms of numbers and weights.

Penalties and Costs

At this stage we have understood that blocks and rules are key inputs to the runcutting process. But in the end, our runcuts will be measured by their cost. Therefore we must understand the range of costs and penalties that will affect the cost of the runcut.

Penalties and costs will be specifically described in the labor agreement. The scheduler needs to be aware of all relevant penalties. When reviewing or defining penalties as part of the runcutting process, the scheduler should consider a range of questions. The key issues to consider are noted in the table below.

Bonus/Penalty	Issues To Be Aware Of
Hourly Rate	• What is the base hourly rate? • Is it the same for all run types? • Does it vary by day of week (particularly on weekends)? • Are there time-of-day pay rate differences (e.g., late night or overnight pay rates)?
Overtime	• At what stage is overtime paid, daily or weekly? • What is the overtime factor (e.g., time and a half, double time, etc.)? • Is the rate the same across all day types?
Guarantee	• What is the daily guarantee? • Is guarantee paid for all run types? • Is guarantee paid on a daily or weekly basis? (depending on how rosters are created this can have significant cost impacts)
Spread	• Is there a spread penalty? At what stage does it apply? • What is the penalty rate (e.g., time and a half, double time, etc.)? • Does the penalty increase for longer spreads (e.g., 1.5 over 10 hours but 2.0 over 12 hours)? • Does the spread penalty apply only to split runs?

Bonus/Penalty	Issues To Be Aware Of
Others	• Are all aspects of a run paid at the regular rate (e.g. are report/clear and relief allowances paid)? • Are penalties cumulative? If a run goes into overtime and has a long spread, are both penalties paid? If so, are they cumulative or multiplicative? If not, which takes precedence? • Are penalties based on all aspects of the work day, or do some parts (such as travel or report/clear allowances) not incur penalties?

In developing runcuts it is imperative to understand the range of penalties that apply and how they interact. For example, if spread penalties are at a higher premium than overtime, it may be more efficient to create more long straight runs. This will incur an overtime cost but avoid split runs and the accompanying (higher) spread premium.

It is also necessary to intimately understand the range of costs and penalties in order to provide an accurate assessment of the cost of a particular runcut solution.

Computers and Costs

Fortunately this is one area where the need for everything to be numerically based is not so difficult. Even at a spreadsheet level it is not difficult to cost runs automatically, based on known costing or penalty rates. For example, a formula to calculate a spread penalty, where the rate is time-and-a-half for all time worked over 10 hours, is quite simple and is shown below:

Type	Run Start	Piece 1 End	Piece 2 Start	Run Finish	Total Spread	Total Work	Spread Penalty	Overtime	Total Cost	
Str	6:00			14:30	8:30	8:30	0:00	0:45	9:15	$115.63
Spl	6:05	9:15	14:15	19:00	12:55	7:55	4:22	0:00	12:17	$153.65

Overtime	8:00
Overtime Rate	1.5
Spread Penalty	10:00
Spread Penalty Rate	1.5
Base Hourly Rate	$12.50

Now already in this simple example we are asking the spreadsheet to calculate different types of penalties based on two different variables (spread and overtime). And then how worked hours are calculated is based upon whether the run is straight or split.

In order to calculate the total dollar cost it is best to express all costs and penalties as hours, and then at the end simply multiply by the base hourly rate to get an actual cost. Below are the formulas used to derive the penalty and cost impacts. As always with schedule spreadsheets, the scheduler should avoid any fixed numbers where possible, and revert to using formulas as often as possible. This reduces the chance of error and ensures values are automatically updated as base inputs (in this case, start and finish times) are changed.

Total Spread	Total Work	Spread Penalty	Overtime		Total Cost
=E8-B8	=IF(D8>0,(C8-B8)+(E8-D8),(E8-	=IF(F8>$C$16,(F8-$C$16)*$C$17,(	=IF(G8>$C$13,(G8-$C$13)*C	=G8+H8+I8	=(J8/0.00069444/60)*
=E8-B8	=IF(D9>0,(C9-B9)+(E9-D9),(E9-	=IF(F9>$C$16,(F9-$C$16)*$C$17,(	=IF(G9>$C$13,(G9-$C$13)*C	=G9+H9+I9	=(J9/0.00069444/60)*

When using computerized systems to evaluate penalties and costs the user should be able to answer the questions in the table above. These can then be converted to formulas and calculated automatically by the system. In the above example, the totals are all calculated, and only the start/finish times or penalty factors are adjusted.

Operator Reliefs

Reliefs are a key part of the basic underlying data required to develop a runcut, however simple or complex they may be. All agencies will have reliefs defined in some form, whether it be informal and based upon existing practices, or defined in detail within a computerized scheduling package.

Do not take existing reliefs as a fixed input. Always question why the current locations are used, the types of reliefs applied, and the relief travel times. This is part of the critical ongoing process of optimizing key scheduling inputs.

Reliefs—An Introduction

What are reliefs? The term is pretty much self-explanatory in that it refers to one operator getting off the vehicle, typically to go on a break or end his or her daily run. The operator is then "relieved" by another operator who takes over operation of the vehicle.

Reliefs can occur at several times of day, including:

- Start or end of a run
- Start or end of a meal break
- Between two pieces of a multipiece run

These actions could be best described as "activities," and the point at which they start or end "activity locations."

relief

The replacement of one operator on a vehicle by another operator on the same vehicle. The first operator may be going on a break or may be ending his/her work day. The second operator may be starting his/her work day or coming back from a break.

relief location

A designated point on a route where operators or crews may be scheduled to begin or end their run or a piece of their run. This can include the garage itself.

car pooling

The use of an automobile to ferry more than one operator between the garage and a relief location, or even between two relief locations.

Defining Reliefs

There are three key considerations in defining relief opportunities. Some of the key factors to be considered are listed below.

1. Relief Locations

Below are some of the key considerations that should be applied when deciding on relief locations:

- Relief locations should be strategically placed to minimize travel times and maximize relief opportunities.
- Proximity to facilities for operators is important.
- Be mindful of operational complexities for street supervisors where there are excessive, multiple relief locations.
- Consider appropriateness of relief locations, including safety issues. May need to limit reliefs at certain locations to daylight hours only, for example.
- Consider the availability of relief cars or buses.

2. Relief Types

There are numerous ways for reliefs to occur. The "type" of relief primarily refers to the means of transport to that on-street relief location from the garage, start point, break location, or other relief location.

The types of reliefs typically used are listed below:

- **Walk.** Where the operator simple walks between the relief location and their next activity location. The activity location may be the garage (for a break or for the start or end of day), another relief location, or other break location. Typically used for short distances only.
- **Car.** Similar to walking, but instead an official agency car is used to ferry crews between relief locations and their previous/next activity point. Many agencies will have fleets of cars used for this purpose. The concept often leads to **car pooling** to relief locations, where multiple crews may share a car travelling to the same or proximate relief location(s).
- **Bus as "taxi."** For this type of relief buses are used to ferry one or multiple operators instead of cars. The buses used for this type of relief would be "spares," notably unused buses in the midday, when most street reliefs occur.

- **Pull.** Pull reliefs also use the bus itself as a means to travel to/from relief locations. But this type of relief actually cuts the block into two separate blocks, rather than bus as taxi, where the in-service block remains intact.
- **Travel as Passenger.** Here the operator travels on an in-service route to or from the relief location. This often works best where a high-frequency service operates past the garage, but can also be utilized to travel between relief locations.

Which relief type is best? As with so many scheduling decisions there is no "best" solution, or simple answer. The types of reliefs used will depend upon a range of factors. The table below provides an indication of the pros and cons of each.

In addition the types of reliefs may be combined. For example one operator may return to the garage using a "pull" relief. On that same bus it is possible to have other operators travelling as passengers back to the garage.

Type of Relief	Pros	Cons
Walk	• Simplest solution for reliefs, requires no vehicle mileage or car fleet • Least likely to result in operational complications	• Limited to locations near the garage, or near to other relief locations
Car	• Fastest and most flexible way to get to remote relief locations • Car mileage is less expensive than bus mileage • Can car pool to achieve multiple reliefs with one car	• Maintaining a car fleet has its own set of logistical and maintenance issues • Complicates scheduling, requires tracking/scheduling of "car blocks" in some cases
Bus as taxi	• Uses available off-peak vehicles for relief trips, avoiding need to purchase a car fleet	• Expensive compared to using car for same purpose • Buses lack flexibility for turning movements needed in some locations • Complicates scheduling of buses, requires "travel trips" to be scheduled into "blocks" • Need to be careful to avoid during peak times or vehicle requirements may increase

Type of Relief	Pros	Cons
Pull	• Operational simplicity as operator changeovers are avoided • Allow better vehicle ownership (can stay with the vehicle all day, even on a split or multipiece run) • Avoids need to cover the layover between trips	• Can increase bus mileage, which is more expensive than car mileage • Need to be careful to avoid pulls during peak times or vehicle requirements may increase
Travel as Passenger	• Avoids need for additional buses, bus mileage, or a car fleet	• Can have reliability implications, since service reliability issues will cause delayed changeovers, resulting in a cascading effect • Expensive compared to using car for same purpose (usually results in longer time) • Complicates scheduling processes if actual scheduled times are used as the travel schedule is built around fixed trip departures (and possibly walk-travel time to a connecting bus). Also requires schedule changes on routes dependent on "travel-in-service" routes used for reliefs when their schedule changes.
Unattended	• Avoids the cost of covering layover time at either side of a relief	• Few agencies (justifiably) are prepared to leave vehicles unattended at relief locations

3. Travel Times

The key message here is to look for precision. Greater accuracy in travel time definition allows two often conflicting key scheduling outcomes (operational reliability and scheduling efficiency) to be better achieved. Some key considerations that should be considered when setting travel times include:

- Differentiate travel times according to the mode used (from the above list).

- Consider time requirements at different times of day. In many cases travel times will differ greatly across different time periods. The same may apply to different service types.
- Understand the time requirement associated with vehicle positioning at relief location bus stops. In some locations this may be significantly different according to which corner the stop is on and which direction it faces.
- When using "travel in service," use actual times instead of average times, as much as possible. Average times tend to generally overstate the time required and result in efficiency losses. Alternatively, there will be some cases where operators are not given enough time to get to the relief location, simply because there is not a trip scheduled to get them there at the right time.

At most (but not at all) agencies the time taken to travel between relief locations and an operator's garage, home, or other relief location will be paid. The times are often defined by schedulers, at times in collaboration with the union.

Most computerized scheduling tools require that scheduling times be specifically defined. This is a good thing as it enforces some consistency in how scheduling data is maintained. Most also allow for exceptions (e.g., for certain times of day).

A word of warning on travel times: times must be set at levels that will allow robust operations. If there is not enough time given to get from a garage to a relief location, the service could run late or have a cascading reliability impact. However, on the reverse side of the equation, excessive travel time can result in simply wasting money.

This applies particularly to agencies who schedule longer runs with more overtime, since the end-of-day travel time will be at time-and-a half in many cases.

The above points imply a need to consistently review, measure, and refine travel times to ensure the right balance between operational reliability and scheduling efficiency.

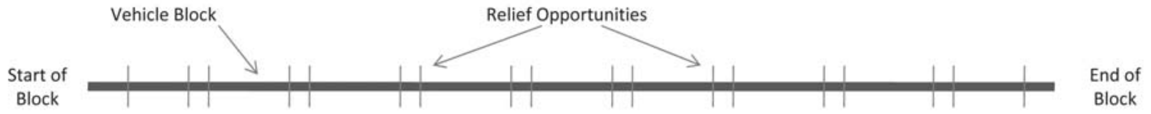
Relief Opportunities

The concept of relief opportunities is critical in understanding how to create a runcut. One of the difficulties presented by creating runs (or daily shifts) for public transportation is the fact that you cannot simply decide when or where to have staff start work, end work, or take meal breaks. These times are all constrained by the blocks or trip themselves, plus where and how reliefs can be enacted.

relief opportunities

Times within a block when reliefs could be scheduled, typically at the end of a trip or when the vehicle passes a specified relief location.

Scheduled reliefs are only known after the runs have been created. Actual reliefs are a subset of the total potential reliefs, or relief opportunities, presented by the vehicle blocks. The diagram below provides an example of the potential relief opportunities for a single uncut block.



In this example there is a single relief location at the end of a trip. The double lines indicate the potential for an operator to be relieved at either the end or the start of a trip. Conventional wisdom suggests that the end of a trip is the best time for a relief, to allow the layover time to cover for unforeseen issues, to accommodate operator changeover time, and to avoid customer inconvenience. Relief locations may also be at trip midpoints. And in some cases routes may have multiple relief locations.

The location and number of relief locations will govern the number of potential relief opportunities. Why is this worth considering? In short, because *the number and location of relief opportunities place one of the most significant mathematical constraints on the runcutting process.* Again, this applies to both spreadsheet and computerized runcutting.

Simply put, more relief opportunities provide more potential options for creating runs. And as noted above, minimizing constraints is a sure-fire way to improve runcutting efficiency. In an extreme example, if you were to have relief locations every minute along a route you would then be able to cut or create pieces at any given minute. As a result it would be simple to create runs of optimum length (optimal being a nebulous term in this example, but assume it means most efficient for now)—just cut the block into pieces of any length as required.

But the reality of transit operations excludes this as an option. The occurrence of reliefs presents a range of operational issues and can affect service quality—driver changeovers can take between one and five minutes. Any scheduled relief has an inherent operational risk due to unreliability of travel times, traffic conditions, or human factors such as lateness for work. Therefore the scheduling of reliefs needs to be undertaken with operational impacts in mind.

One of the key tenets of scheduling is to make for operations that are as simple as possible: the less complex the operation, the less risk of issues occurring. However, as with all things scheduling-related, the tradeoff of complexity needs to be balanced against efficiency.

So we have a classic scheduling conundrum—mathematically it will almost certainly be cheaper to allow numerous relief locations and relief types. But operationally we would like to limit the number of relief locations and opportunities.

In general agencies tend to define relief locations at places where travel time will be minimized, access for buses and/or cars is good, the location is safe, or there are other strategic benefits (such as it is near an acceptable bathroom, meal location, or a junction of several routes).

Basic Runcutting

Defining Our Objectives

Before the runcutting process can begin, the scheduler needs to be sure that all the necessary inputs are in place. These inputs were described in some detail in the previous section and included:

- trips and vehicle blocks;
- rules and constraints; and
- relief types and travel times.

Runcutting is like a puzzle with many solutions. There is no single “right answer,” but there is an answer that most closely matches the objectives of your agency.

Before doing any detailed work we need to clearly understand our objectives. What are we trying to achieve when creating this runcut? It could be any combination of the following:

- To minimize operating costs
- To minimize the number of split runs
- To minimize the number of trippers
- To evenly distribute the work among the operators
- To ensure all reliefs are at one particular location
- To maximize long runs for AM starts
- To make the runcuts more “operations-friendly”
- To ensure all runs are legal (this is often overlooked)
- To achieve a target distribution of full-time and part-time work based upon labor agreements and/or current manpower availability

These are only a few of the possible objectives that could define what we are trying to achieve. There are many more, and we’ll discuss some of those later. For now just be sure to jot down

Tip It is essential for the runcutter to both understand the "rules" for your property and to know which ones can never be violated, and which ones may be "bent" when there are no solutions that meet all of the requirements. Often bending the rules requires management approval, and the runcutter must understand the process before beginning.

Tip To get a quick estimate of the total runs required:

Runs = vehicle hours/
desired run length

.

what the key objectives are before you start, and know that at times these may even conflict with one another. But the key thing here is to be clear on your objectives.

Work Rules

One of the objectives of any runcut is to ensure that the runs are "legal"—meaning they conform both to the employment laws in your jurisdiction and to the requirements of your labor agreement. The table below lists some fairly typical types of work rules that we will use in creating this first runcut. Before you begin a runcut for your property, make sure you are familiar with all of the requirements that affect legal runs.

Work Rule	Requirement
Minimum Platform Time (full-time run)	6:00
Maximum Platform Time	10:00
Minimum Platform Time (tripper)	2:00
Maximum Platform Time (tripper)	5:59
Report Allowance (start of run)	0:15
Clear Allowance (end of run)	0:15
Clear Allowance (end of first half of split run)	0:05
Report Allowance (start of second half of split run)	0:15
Maximum Spread	13:00
Run Type Limits	50% minimum straight runs 25% maximum split runs 25% maximum trippers
Guarantee (Daily)	8:00
Overtime (Daily)	Time and a half over 8:00
Spread Penalty	Time and a half over 10:00
Reliefs	Must be at "Point A" All reliefs are taken as travels using a car 0:10 travel time from garage to Point A

Knowing the Answer

So now we're ready to jump in and create the runs, yes? No! Because runcutting has many possible solutions, but only one optimal result, it is essential that we get as much information as possible before we begin cutting. We begin with a number of techniques that allow us to approximate the solution to the runcutting puzzle before we begin the cut itself.

Let's start with our basic Route 97-Broad Street schedule example—the solution with a 15-minute peak and 30-minute off peak service.

There are a few simple things we can look at. Firstly we could simply divide total vehicle hours by a desired average platform time per run to come up with an estimate of total runs. To come up with an average platform time you could look at your existing operating information—on average how much travel, sign, or "non-platform" time does each run have (just stick with averages here). In our case we know the garage is 10 minutes from Point "A." We will assume a 15-minute report allowance at the start of a run and a clear allowance of 15 minutes at the end. Therefore any run will have at least 40 minutes of non-platform time (15 sign on allowance, 15 sign off allowance, and probably at least one 10-minute travel). This means we would want to cut runs with somewhere around 7:20 platform time to reach our desired eight hours. Below are the blocks we produced earlier.

For many transit operators, the desired run length will be eight hours minus time allowed for sign in and sign out and travel time.

Hours Summary

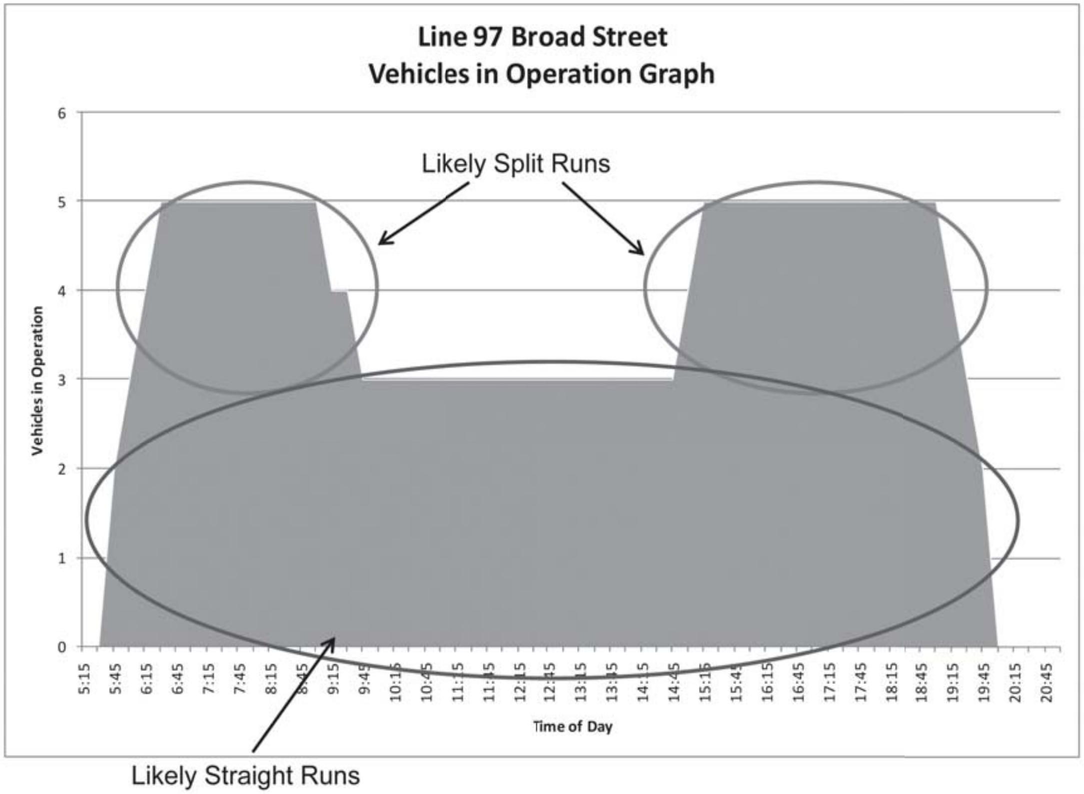
Block	Garage Depart	Garage Arrive	Hours
1	5:46	9:19	3:33
2	6:01	18:38	12:37
3	5:50	18:19	12:29
4	6:05	9:38	3:33
5	6:20	19:53	13:33
6	15:01	19:49	4:48
7	15:20	19:19	3:59
Total			**54:31**

This gives us a total of 54 hours. If we assume 7:20 hours of platform time per run we come up with an estimate of 7.5 runs. Of course 7.5 isn't a viable number of operators so we'll assume that we are looking at either 7 or 8 runs.

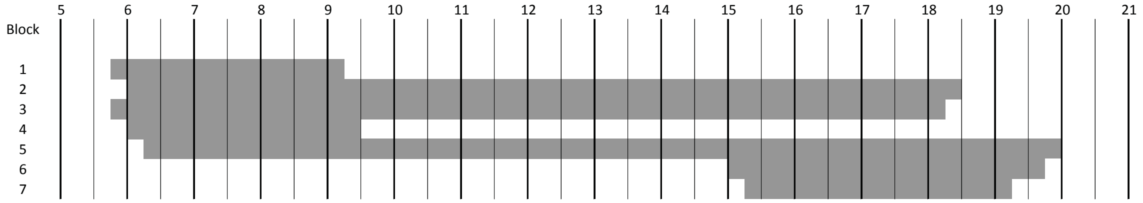
What else can our blocks tell us about the optimal runcutting solution? Let's go back and deconstruct the "Vehicles in Operation Graph" from the previous section. What does it tell us? We can see there are three vehicles operating during the day and five during the peaks.

Immediately that suggests we will have either two split or four trippers, to cover those additional peak blocks. That leaves us with three all-day blocks, each operating well in excess of the allowable platform time for a straight run. These blocks will therefore need to be cut, potentially into two straight runs each. But as these blocks are only between 12 and 13 hours in length we can also expect shorter straight runs, possibly with some guarantee time.

By this stage of our analysis we now have an idea of not only how many runs but also of the likely breakdown of those runs by run type and the potential for guarantee time—all without doing any runcutting at all! This is what we mean by "knowing the answer" before starting.



As we've stated elsewhere, many scheduling tasks are made easier by simple graphical representation of the information rather than detailed numerical tables. This applies equally to runcutting tasks. A good visualization tool is to lay out the blocks in a graphical manner as shown below.



While the times are rounded to 15-minute segments, it enables us to pretty quickly see block lengths and suitability for run types. For example blocks one, four, six, and seven appear suitable for split run or tripper pieces, and blocks two, three, and five appear suitable for straight runs.

Creating the Runs

The hard work is far from done. Although we have an idea of how the runcut will look, we need to work through the detail of that runcut and create the runs.

Looking back at our graphical blocks diagram we have a good idea that blocks one and four will combine with blocks six and seven to create two split runs. And we expect to cut blocks two, three, and five into two straight runs each. However the graphic does not provide enough detail about specific times and locations. So we turn back to the schedule.

Let's start by trying to cut Block 2 into straight runs. Block 2 starts at 6:01 and ends at 18:38, totaling 12:38. Our run gets 15 minutes report allowance and so signs on at 5:46. We'd like to be as close to eight hours as possible (to avoid guarantee or overtime) and so ideally we would like to finish at around 13:46. Allowing for 15 minutes of clear allowance, and 10 minutes of travel time, that means we would like to cut the run at around 13:11. But the only relief opportunities (i.e., the times that the bus passes Point A) in this time vicinity are at 12:09 or 13:39. So we have a judgment call to make, and it has implications for not only the AM run but of course the PM run also. The best thing is to look at the two options and see the implications as below.

Tip Runcutting, scheduling, and planning are often iterative processes. When you begin your runcut, you may notice that adjusting the schedule slightly can either add service at no cost, or could save significantly with a slight trim. Good schedulers do not just cut what's in front of them, but make sure everyone responsible understands the implications of the schedule.

Option 1 - Cut at 12:09

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Travel Hours	Total Hours	Spread	Guarantee	Overtime	Spread Penalty	Paid Hours	Pay/ Plat
				Time	Place	Type	Time	Place	Type											
1	Str	2	5:46	6:01	Garage	Pull	12:09	A	Street	12:34	6:08	0:30	0:10	6:48	6:48	1:12	0:00	0:00	8:00	1.304
2	Str	2	11:44	12:09	A	Street	18:38	Garage	Pull	18:53	6:29	0:30	0:10	7:09	7:09	0:51	0:00	0:00	8:00	1.234
											12:37	**1:00**	**0:20**	**13:57**		**2:03**	**0:00**	**0:00**	**16:00**	**1.268**

Option 2 - Cut at 13:39

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Travel Hours	Total Hours	Spread	Guarantee	Overtime	Spread Penalty	Paid Hours	Pay/ Plat
				Time	Place	Type	Time	Place	Type											
1	Str	2	5:46	6:01	Garage	Pull	13:39	A	Street	14:04	7:38	0:30	0:10	8:18	8:18	0:00	0:09	0:00	8:27	1.107
2	Str	2	13:14	13:39	A	Street	18:38	Garage	Pull	18:53	4:59	0:30	0:10	5:39	5:39	2:21	0:00	0:00	8:00	1.605
											12:37	**1:00**	**0:20**	**13:57**		**2:21**	**0:09**	**0:00**	**16:27**	**1.304**

The answer in both cases is "not good!" Both options result in substantial guarantee time. Why? Block 2 is only 12:37, which allows an average of 6:18 of platform time. Even adding the travel, report, and clear allowances this only gets us to an average run length of 7:00, meaning somewhere around an hour of guarantee time for each run. In this case we choose to cut the blocks at 12:09 since this incurs the minimum total cost. However we would be looking for other solutions as we cut the runs since we have incurred some serious inefficiency in the first two runs. In the end we will choose Option 1 based upon the fact that it incurs 27 less minutes of paid time. Is 27 minutes important? The answer is an emphatic "yes!" In scheduling every minute matters.

To illustrate this point let's consider the costing impacts of that 27 minutes. Over a year (assuming 255 weekdays) that comes to a total of 114.75 hours. At a base hourly rate of $20 that comes to over $2,000, which will end up more once variable benefits are applied. From this example we can use a rule of thumb that every hour of paid time equates to over $5,000 annually—that's why not wasting any paid time in every situation is critical.

We will push ahead and cut straight runs from Blocks 3 and 5 (the other two all day blocks) in the same manner as we cut Block 2. Again we need to decide when to cut the block to minimize the overall paid time while keeping the runs legal. In this case if we cut Block 3 at 11:09 the first run becomes less than six hours, so we are forced to cut it at 12:39. We cut Block 5 at 13:09 as that option best balances the work hours of the AM and PM runs.

Our runs summary now looks like the following:

Option 1 - All Long Blocks Now Cut

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Total Hours	Spread	Guarantee	Overtime	Spread Penalty	Paid Hours	Pay/ Plat
				Time	Place	Type	Time	Place	Type									
1	Str	2	5:46	6:01	Garage	Pull	12:09	A	Street	12:34	6:08	6:48	6:48	1:12	0:00	0:00	8:00	1.304
2	Str	2	11:44	12:09	A	Street	18:38	Garage	Pull	18:53	6:29	7:09	7:09	0:51	0:00	0:00	8:00	1.234
3	Str	3	5:35	5:50	Garage	Pull	12:39	A	Street	13:04	6:49	7:29	7:29	0:31	0:00	0:00	8:00	1.174
4	Str	3	12:14	12:39	A	Street	18:19	Garage	Pull	18:34	5:40	6:20	6:20	1:40	0:00	0:00	8:00	1.412
5	Str	5	6:05	6:20	Garage	Pull	13:09	A	Street	13:34	6:49	7:29	7:29	0:31	0:00	0:00	8:00	1.174
6	Str	5	12:44	13:09	A	Street	19:53	Garage	Pull	20:08	6:44	7:24	7:24	0:36	0:00	0:00	8:00	1.188
											38:39	**42:39**		**5:21**	**0:00**	**0:00**	**48:00**	**1.242**

Again we can see that the runs are generally inefficient, each resulting in guarantee time. At about this stage we may want to go back, rethink the schedules, and note that it would be possible to extend the hours of operation, by one round trip for each vehicle, with minimal cost impact. The cost impact would be minimal as the additional hours would be absorbed by the available guarantee time, meaning the additional paid hours would be negligible. The real cost would be the variable vehicle costs, and these tend to form only a small percentage of total operating costs. But we should leave such decisions until we have worked through all the runs, both straights and splits.

Next we might create split runs from the smaller peak blocks. We have four peak blocks (Blocks 1, 4, 6, and 7), two in each peak. These should be able to form two split runs. We can simply list the appropriate blocks as follows to get an idea of how the runs will look.

Block	Garage Depart	Garage Arrive	Hours
1	5:46	9:19	3:33
6	15:01	19:49	4:48
	Spread	*14:33*	
	Work Hours	*9:11*	
4	6:05	9:38	3:33
7	15:20	19:19	3:59
	Spread	*13:44*	
	Work Hours	*8:22*	

Now we have two split runs. The block lengths result in these runs being longer than the straights. We'll assume that is acceptable and push ahead.

This gives us two splits and six straights, a total of eight runs. All blocks are covered and we must be done, right? Wrong! Go back and look at the split runs—they fail the very first test of meeting our scheduling criteria—they are not legal! The two split runs are well in excess of the 13-hour maximum spread mandated by our labor rules.

This leaves us some potentially difficult decisions. The simplest solution here could be to use some trippers. But the Labor Agreement only allows a maximum of 25%, in effect meaning two of our eight. That would still leave us with two blocks not yet assigned to runs.

One of the lessons we are learning here is that runcutting small solutions is often the most difficult of the runcutting tasks that can be undertaken. Going back to the math, there are simply fewer options for cutting and hooking pieces in a manner that will allow a feasible solution. For some small runcutting problems there may in fact only be one feasible solution possible.

So what are our options at this point? Let's note them and discuss the pros and cons:

- Create four trippers, one for each of the peak blocks . As noted above this is the simplest procedure but fails to meet the 25% maximum rule. There may be an opportunity to negotiate with the union and allow some variation to the labor rules, or to let one or two runs through that don't meet the rules. This is not the preferable option but at times may be the most pragmatic, particularly if faced with tight timeframes.
- Revisit the schedules and blocks, potentially reducing the spread of some of the blocks to allow the split runs to fall within the 13-hour spread limit. Or at least adjust one of them this way and leave the other two peak blocks as shorter part-time pieces. This can be an expedient approach for runcut purposes but may affect desired service level outcomes.
- Revisit the entire process and recut the pieces to allow "better" runs to be cut, and a legal solution to be created. This approach, assuming it allows us to find a solution, is often preferred as it allows us to meet our runcut objectives without affecting the schedule or blocks.
- Revisit the blocking to allow blocks that will cut into runs in an efficient manner. This is of course the approach that will take the most time and could affect the schedule itself.

Another key lesson we are learning is that the schedules and blocks cannot be written in isolation from the runcut process. To do so is to ignore the fact that scheduling is an integrated and holistic process that requires all aspects to be considered. The scheduler who undertook the blocking would have given an indication of the costing impacts of the proposed schedule, based on the blocks developed. Right now those costs are probably completely inaccurate as the runcuts are not able to be provided efficiently with the initially developed blocks.

For the sake of expediency we will assume that in this case we are allowed one split run to go over the 13-hour spread maximum. In practice this is not an option for the scheduler but for now we will make this assumption as it allows us to see how the process unfolds. This will allow us to create one split run and two trippers from the four peak blocks.

How does one choose which is the split and which will be the part-time blocks? In this case we choose the combination of blocks that minimizes the spread of our split run—Blocks 4 and 7. Blocks 1 and 6 then become two trippers.

Well done—we now have a completed runcut. Our **run guide** now has a completed runcut and is provided below.

run guide

A summary of runs that describes start/finish locations, work hours, and cost element breakdowns. The Run Guide is the principal document that describes all of the runs available for bid.

Option 1 - Completed Runcut

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Travel Hours	Total Hours	Spread	Guarantee	Overtime	Spread Penalty
				Time	Place	Type	Time	Place	Type									
1	Str	2	5:46	6:01	Garage	Pull	12:09	A	Street	12:34	6:08	0:30	0:10	6:48	6:48	1:12	0:00	0:00
2	Str	2	11:44	12:09	A	Street	18:38	Garage	Pull	18:53	6:29	0:30	0:10	7:09	7:09	0:51	0:00	0:00
3	Str	3	5:35	5:50	Garage	Pull	12:39	A	Street	13:04	6:49	0:30	0:10	7:29	7:29	0:31	0:00	0:00
4	Str	3	12:14	12:39	A	Street	18:19	Garage	Pull	18:34	5:40	0:30	0:10	6:20	6:20	1:40	0:00	0:00
5	Str	5	6:05	6:20	Garage	Pull	13:09	A	Street	13:34	6:49	0:30	0:10	7:29	7:29	0:31	0:00	0:00
6	Str	5	12:44	13:09	A	Street	19:53	Garage	Pull	20:08	6:44	0:30	0:10	7:24	7:24	0:36	0:00	0:00
7	Spl	1	5:31	5:46	Garage	Pull	9:19	Garage	Pull	9:24	8:21	0:50	0:00	9:11	14:18	0:00	0:35	2:09
		6	14:46	15:01	Garage	Pull	19:49	Garage	Pull	20:04								
8	Pt	4	5:50	6:05	Garage	Pull	9:38	Garage	Pull	9:53	3:33	0:30	0:00	4:03	4:03	0:00	0:00	0:00
9	Pt	7	15:05	15:20	Garage	Pull	19:19	Garage	Pull	19:34	3:59	0:30	0:00	4:29	4:29	0:00	0:00	0:00
											54:32	**4:50**	**1:00**	**60:21**		**5:21**	**0:35**	**2:09**

Note that in the above spreadsheet there are as many formulas as possible, holding true to our previously stated aim of avoiding typing numbers that can be calculated in every possible circumstance, no matter how complex the formula.

Now we need to carefully check that we have all trips covered, all runs are legal (except for the agreed Split Run), that our numbers add up, and that the totals are calculated correctly. You should have a checklist and templates to assist with this process.

One solution is to go back and review our graphical depiction of the blocks. For each block, "color in" or trace over the pieces and runs. This way we can be clear that the runcut covers the blocks entirely.

The table below summarizes the total cost of the runcut.

Runcut Summary

	Solution 1		
Straight Runs	6	67%	
Split Runs	1	11%	
Total FT Runs	7	78%	
Part Time Runs	2	22%	
Total Operators Required	9		
Hours Breakdown	Total	%	Avg
Platform	54.5	90%	6.1
Report	4.8	8%	0.5
Travel	1.0	2%	0.1
Total Work Hours	60.4		6.7
Penalties		%	Avg
Spread	2.2	3%	0.2
Overtime	0.6	1%	0.1
Guarantee	5.4	8%	0.6
Total Paid Hours	**68.5**		
Pay/Plat Ratio	1.2553		

As the table shows, we have seven full time and two trippers. The total weekday paid hours are 68.6, and we have a ratio of driver pay hours to total platform hours (pay/plat ratio) of 1.255.

So is this a "good" runcut? To answer this question go back and review against the original stated objectives. Clearly there is some inefficiency in the runs—over 12% of the cost is incurred in guarantee, spread, and overtime penalties. But these are a function of the constraints of the runcut (the rules and the blocks we started with) more than a reflection of the competency of the runcut itself. We would also need to look at historical trends for the route and the agency to understand if the solution fits in within normal bounds.

Reliefs

No job is over until the details are done. There are still a few things that need to be completed before the runcut can be considered final (assuming the agency decides that this is the runcut to implement).

A key task relates to reliefs. The rules stated that all travels to relief locations must use a car. Generally this will mean that an agency has a car or fleet of cars that operators use to get to and from relief locations. We need to be sure we have enough cars for the travels dictated by the runcut. To be sure this is the case each travel required by the runcut should be listed—in effect a list of "trips" that need to be scheduled into a "block" to be operated by the car (or cars).

Car Trips

Driven By Run #	Leave Garage	Arrive Relief	Driven By Run #	Leave Relief	Arrive Garage
1	11:59	12:09	2	12:09	12:19
3	12:29	12:39	4	12:39	12:49
5	12:59	13:09	6	13:09	13:19

In this case the one car will be able to undertake each of the relief trips required. However, there may be cases when multiple reliefs occur at the same time, or at different locations, and more than one car could be required. In such cases a separate scheduling task is required to match cars to reliefs (in the above manner) to obtain car vehicle requirements.

Information and Outputs

Now it is a matter of generating the appropriate outputs and distributing them accordingly. Most transit agencies have their own specific set of reports or outputs for distribution. Therefore we will not provide samples here, but just list those that are typical.

- **Run Guide.** The run guide displays a summary of each run—where it starts, finishes etc., along with information about the length of runs. It may also include a breakdown of hours and penalties. This report is used across the organization as a means of quickly reviewing runs.
- **Paddle.** The paddle comes in many shapes, sizes, and formats. The aim of the paddle is to provide the operator with information regarding his or her workday—what time the work day starts/ends, how to get to/from relief locations, and the trips to be operated (complete with times at all timepoints).
- **Headway Sheet.** We include this in runcutting as it may be helpful to operations staff at this stage if the **run number** for each trip is included.

Automating the Runcut

The above process used spreadsheets to develop a runcut. However the majority of transit agencies now use computerized scheduling software packages to generate runcuts automatically.

Why bother with manual techniques then? As stated previously it is necessary to understand the manual techniques in order to understand, and be able to review, the solutions provided by automated scheduling systems. Many schedulers make the mistake of setting up basic parameters and then "pressing the button" to produce a completed automatic runcut.

Our experience is that it is extremely difficult to model all of the subtleties in a format (i.e., a logical or mathematical statement) that will allow a computerized system to fully automate. The more likely outcome is that solutions will be produced that achieve most of the aims of a runcut but require some manual intervention or tweaking to finalize.

Great care must be taken to define all rules, constraints, and preferences to meet the runcut objectives. Take our above example as a good case. Here we were able to agree to allow one "bad" run with a spread above the maximum allowed. However if we used an automated system, with a hard limit of 13 hours set, it would not have been capable of generating the solution we created manually. This is an example of where the skill and experience of the scheduler are required to assist the automated tool to generate an outcome. In this example we may

paddle

An output of the scheduling process that provides the operator with information regarding his or her workday—what time the work day starts/ends, how to get to/from relief locations, the trips to be operated, and times at all timepoints. If an operator drives on more than one route in the day, the paddle will have all trips shown sequentially, as well as travel paths between routes if needed. The paddle may also include a list of route turns, route maps, farebox, headsign, and radio codes, and key intersections and stops that must be announced.

run number

The unique number assigned to each work assignment on a specific day.* At some systems, the run number is unique only when used in combination with a designator for the garage or the route or route group number.

*Throughout this chapter, we have simplified the examples by referring to Run 1, Run 2, etc. Obviously, these numbers are not unique. In practice, agencies typically use multi-digit run numbers that can include the route or route group number, a garage identifier, a code for weekday/Saturday/Sunday, and a code for time of day. Each of these run numbers is unique on any given day.

have needed to manually create and then force or fix the run before resubmitting the runcut. Only then could the computerized system have generated the same solution.

The computerized system will significantly enhance the ability of the scheduler to produce runcuts if the scheduler is aware of how to make the most of the system as a tool, and not as a solution itself. Computerized systems also significantly enhance the final parts of the process—error checking and report production—to provide a level of automation and accuracy not otherwise possible.

Other Factors

Before ending the basic section, it is worthwhile to cover a few qualitative issues that can sometimes get lost in the quest for efficiency.

The first issue is operator fatigue. Even in the absence of rules limiting spread time, it is a good idea to ensure that an operator's day is not too long. The scheduler's biggest concern regarding fatigue is to make sure that rostered operators get at least eight hours off between work shifts, whether or not this is spelled out in the labor agreement.

Another issue is how "optimal" runcuts are defined. Cost, number of drivers, and number of buses are all extremely important factors, but poor run structure (and poor rostering) can create morale problems, leading to higher turnover rates and increased recruitment and training costs. These factors could eventually outweigh any cost efficiency benefits. A good scheduler will balance working conditions and efficiency factors in the runcutting process.

LEVEL 1

End of Basic Runcutting.

The Intermediate Section of Runcutting continues on the next page.

To jump to Rostering, go to page 6-1.

5.2 Intermediate Runcutting

LEVEL
2

In the previous section we looked at some basic runcutting concepts and worked through a relatively straightforward example. However even in a "straightforward" example we ran into some difficult issues and had to make a number of decisions. This only serves to highlight the complexities of runcutting.

It should be noted that every agency, and every scheduler, approaches runcutting slightly differently. There are no universal approaches that can be applied to every scenario, since the inputs (described below) will rarely be the same from one agency to the next—most agencies will have at the minimum subtle differences in policies or work rules. And of course the blocks, relief locations, travel times etc. will always be different.

Runcutting Inputs

In the previous section we defined the required runcutting inputs to include a complete set of trips and vehicle blocks, all relevant defined rules, defined relief types and travel times, and known limitations, such as cost limits or work rule preferences.

To produce effective runcuts the scheduler needs to work with a complete picture of what is required, and with a full set of the necessary input data. This applies to runcutting solutions of any complexity, size, or nature.

As runcutting gets more complicated it is important to have several additional documents available to the scheduler:

- **The Schedule.** As we are creating detailed runs with specific times at relief locations we obviously need to see the detail of the schedule. Runcutting seldom changes the actual service schedule, which is often designed around service considerations.
- **Blocks Summary.** In order to match up starts and finishes, and to view the blocks in a summary form, we need to generate a blocks summary. This summary can simply show, for each block, the start and finish times, total length or duration, vehicle type, and garage.
- **Blocks Diagram.** This is the key tool in developing the runcut at a conceptual level. The blocks diagram simply shows one line or bar per block. Use of a spreadsheet for creating the blocks diagram is critical, including effective use of color-coding (as we will see throughout this section). If a blocks diagram is not a routine output of the run blocking process the runcutter will need to create a blocks diagram before beginning the runcut.

Tip A block summary and block diagram are often generated during the blocking step of scheduling. However, blocks may be altered by the runcutting process, making these important inputs AND outputs of the runcutting process.

Runcutting Outputs

It is important that the outputs of the runcutting process be standardized as well. The following outputs are an integral part of developing runcuts.

- **Run Guide.** The run guide provides information about each run—start/finish time and location, total hours, type of relief, etc. It is built as the runs are created. As with all tools, if a spreadsheet is being used, maximize the use of formulas and minimize the use of "typed in" values.
- **Runs Summary.** The runs summary, produced at the end of the basic runcutting section, provides an overview of the totals of the runcut, including a breakdown of the components of runs (platform time, travel time, etc.). In some situations the Run Guide and the Run Summary may in fact be the same document or spreadsheet.

When using a computerized scheduling system, many of the above items are provided automatically and can be viewed interactively (e.g., looking at the schedule while cutting runs). When using other approaches, spreadsheets and/or databases should be utilized as much as possible to minimize manual calculations, reduce errors, and improve the overall runcut quality.

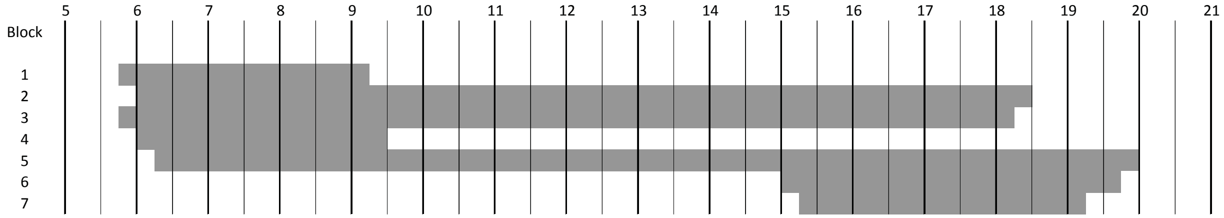
Trips and Blocks

The basic section of the blocking chapter provided an important tip: "Blocking is not done in isolation—it is an intermediate step between writing a schedule and developing driver assignments, and must be done with the ultimate goal of developing efficient and legal driver work pieces." However a typical blocking solution will focus more on the needs of the blocking process, and will not necessarily provide blocks that will cut neatly or efficiently into a final solution.

With this in mind we can revisit our runcut for Line 97. Again we start with a completed set of trips and vehicles blocks. But this time we will start with a significantly different view—that the blocks can potentially be adjusted as necessary to allow a more effective runcut to be produced. Let us explore this a little further by using the example from the previous runcut.

The key issue we had was the length of the splits, or the start/finish times of the peak pieces that we assumed would form those splits. In the previous section, the beginning runcutter was told to consider the blocks as fixed, which left some significant issues that resulted in a potentially less efficient runcut. The solution developed in that example required adding an operator (we used two part-time runs instead of one split).

Looking at the diagram of our blocks we can see that there are actually some starts and finishes that, if combined, would allow us to create split runs within the prescribed 13-hour spread.



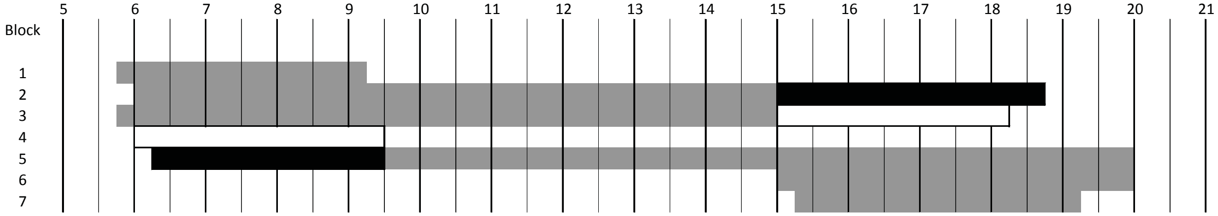
In particular we are referring to matching the start times of Blocks 4 and 5 with the end times of Blocks 2 and 3. Looking at the start/finish times of our blocks below we can get a sense of whether this would allow split runs to be created within the 13-hour spread limit.

Hours Summary

Block	Garage Depart	Garage Arrive	Hours
1	5:46	9:19	3:33
2	6:01	18:38	12:37
3	5:50	18:19	12:29
4	6:05	9:38	3:33
5	6:20	19:53	13:33
6	15:01	19:49	4:48
7	15:20	19:19	3:59
Total			**54:31**

Block 4 starts at 6:05 (meaning a sign-on time of 5:50) and Block 3 ends at 18:19 (meaning a sign off time of 18:34). Block 5 starts at 6:20 (6:05 sign on) and Block 2 ends at 18:38 (sign off of 18:53). This means we have sign-ons at 5:50 and 6:05 to match with sign offs at 18:34 and 18:53. Logic tells us that the 5:50 sign on could not be paired with the 18:53 sign off as the spread would be 13:03. So we need to match the 5:50 sign on (Block 4) with the 18:34 sign off (Block 3), and match the 6:05 sign on (Block 5) with the 18:53 sign off (Block 2). This would give us two split runs with spreads of 12:44 and 12:48, respectively.

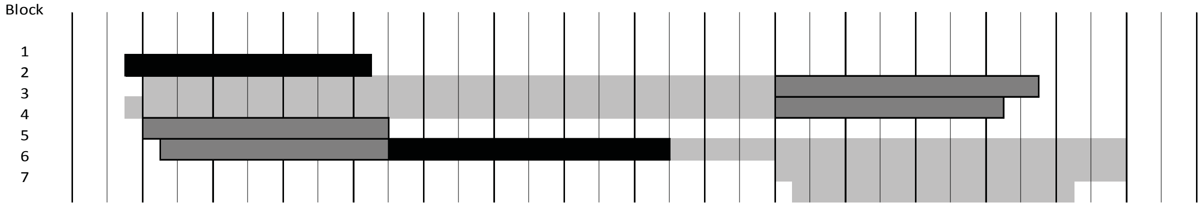
The trick is to now generate pieces of work that will allow us to create two split runs with the above start and finish times. In essence we are trying to achieve what is shown in the following diagram. The two white pieces represent the matching of Blocks 4 and 3 into one split run. The black pieces represent the matching of Blocks 5 and 2 into another split run.



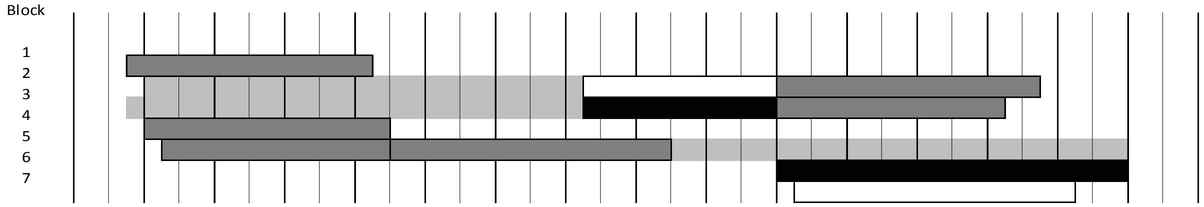
There are several ways to achieve this outcome. These are described below.

1. *Recut the Pieces*

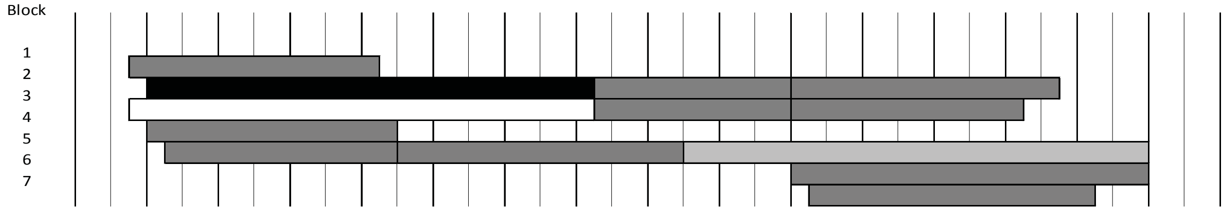
We cut the blocks into pieces as shown, using street or car reliefs, and create the runs accordingly. If this approach was used we would be left with one piece of Block 1 and a piece of Block 5 (from 9:30 AM onwards) to be matched together to form a straight run. In effect the operator would cover Block 1, pull into the garage, and then travel back out to make the relief on Block 5 at around 9:30 AM. This is known as a two-piece or a multipiece run. The swing time between the two pieces would be paid. In practice, it is much more likely with a short swing time that the bus would remain on the street, either laying over or deadheading to the starting point of the next trip. Assuming Block 5 was then cut at 13:34 (the same as our previous runcut) it would look something like the following diagram—the black run.



We then follow the same process for Blocks 2 and 3 (the PM pieces of our two split runs). The cuts are made at around 15:00, leaving the PM pieces of Blocks 2 and 3, both of which start around 12:15, to be matched with Blocks 6 and 7 to create two multipiece straight runs. Again this is presented diagrammatically in the following figure. We have added two more multipiece straight runs, the white and black runs.

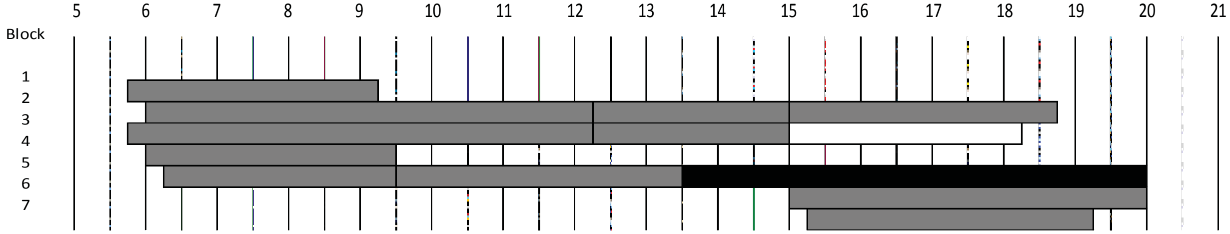


This leaves us with three more straight runs to create—the AM pieces of Blocks 2 and 3, and the PM piece of Block 5. When created our completed diagram looks like the following.



At this stage of course we have only created the runs conceptually and assumed a relief opportunity will occur somewhere around the time required. Before we complete this runcut we need to optimize relief times based on the actual schedule. On the diagram below, we make a subtle change where the PM split piece on Block 3 (white) is pushed forward a little earlier (to around 14:30) to allow enough time for the relief to be made, and our straight white run enough time to make the relief, return to the garage, and begin Block 7. Again, with a short swing time like this, it is much more likely that the bus would remain on the street. On Block 5 for example we assumed a possible relief around 10 AM. Fortunately, looking at the schedule, we see that there is a relief opportunity at 10:09. It pays to look at specific potential relief times as you create the conceptual runs in the diagram.

Next we work through the details of specific relief times and create the runs summary. The finished product is presented below.



We also made some changes to the conceptual runcut to minimize any overtime costs. If you compare with the previous diagram you can see we cut Block 5 earlier (at 13:09). Below is our updated runs summary, color-coded to match the conceptual run diagrams developed above.

We also need to consider the operational impacts of the revised runcut. Note in particular that Run 6 has an issue. The cut at 15:09 means an arrival back at the garage at 15:19. The run is then supposed to operate Block 7, a pull out, at 15:20. This leaves only 1 minute and that assumes the 15:09 relief is made on time and the 10-minute travel time back to the garage is achievable. Clearly this solution would create the potential for the 15:30 trip from Point A (the first in-service trip on Block 7) to run late on a consistent basis. It is likely that the bus would remain on the street in this situation as well.

Importantly we have now eliminated the split run of greater than 13 hours—we had initially allowed this to illustrate the spread issues resulting from initial vehicle blocks. In reality this run, as shown in the initial solution, invalidated the entire run cut. Here we have found a more innovative approach and dealt with this problem successfully.

We have also added some general complexity and potential service instability with the multipiece runs and multiple reliefs. In general, simple is better for ease of operation. We need to be mindful as to whether the potential efficiency gains warrant the potential service quality impacts. This is a question that the scheduler must continually be asking as solutions are developed and is central to the production of good scheduling outcomes.

Completed Runcut - Pieces ReCut

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Paid Break	Travel Hours	Total Hours	Spread	Guarantee	Overtime	Spread Penalty	Paid Hours	Pay/ Plat
				Time	Place	Type	Time	Place	Type												
1	Str-M	1	5:31	5:46	Garage	Pull	9:19	Garage	Pull		6:33	0:30	0:40	0:20	8:03	8:03	0:00	0:01	0:00	8:04	1.233
		5		10:09	A	Street	13:09	A	Street	13:34											
2	Str	3	5:35	5:50	Garage	Pull	12:39	A	Street	13:04	6:49	0:30		0:10	7:29	7:29	0:31	0:00	0:00	8:00	1.174
3	Str	2	5:46	6:01	Garage	Pull	12:09	A	Street	12:34	6:08	0:30		0:10	6:48	6:48	1:12	0:00	0:00	8:00	1.304
4	Spl	4	5:50	6:05	Garage	Pull	9:38	Garage	Pull	9:43	7:43	0:50		0:10	8:43	12:44	0:00	0:21	1:22	10:26	1.353
		3	13:44	14:09	A	Street	18:19	Garage	Pull	18:34											
5	Spl	5	6:05	6:20	Garage	Pull	10:09	A	Street	10:24	7:18	0:50		0:20	8:28	12:48	0:00	0:14	1:24	10:06	1.384
		2	14:44	15:09	A	Street	18:38	Garage	Pull	18:53											
6	Str-M	2	11:44	12:09	A	Street	15:09	A	Street		6:59	0:30	0:01	0:20	7:50	7:50	0:10	0:00	0:00	8:00	1.146
		7		15:20	Garage	Pull	19:19	Garage	Pull	19:34											
7	Str-M	3	12:14	12:39	A	Street	14:09	A	Street		6:18	0:30	0:42	0:20	7:50	7:50	0:10	0:00	0:00	8:00	1.270
		6		15:01	Garage	Pull	19:49	Garage	Pull	20:04											
8	Str	5	12:44	13:09	A	Street	19:53	Garage	Pull	20:08	6:44	0:30		0:10	7:24	7:24	0:36	0:00	0:00	8:00	1.188
											54:32	**4:40**	**1:23**	**2:00**	**62:35**		**2:39**	**0:37**	**2:46**	**68:37**	**1.258**

The result of this revised runcut is basically no change in total paid hours (68:37 as opposed to 68:27 in the previous cut). But we have reduced total operators required by one—in effect replacing two part time runs with one full-time split run. The benefits and costs of full-time and part-time runs will be discussed further in the next section. However, generally fewer runs mean reduced travels and report allowances. It may also reduce benefit costs when part-time operators are given paid benefits by the agency.

We have also reduced the make-up time from over five hours to 2:39 (make-up time is one of the least productive components of paid time). This is offset to some extent by the introduction of 1:23 of paid break—the intervening time between two pieces of the multipiece straight runs.

Overall we could consider this to be a good result with no paid hours increase but a manpower reduction. And we achieved this without any change to the blocks or scheduled trips. A further refinement step could be undertaken to reconsider where the cuts were made with a view to offsetting any guarantee and overtime costs.

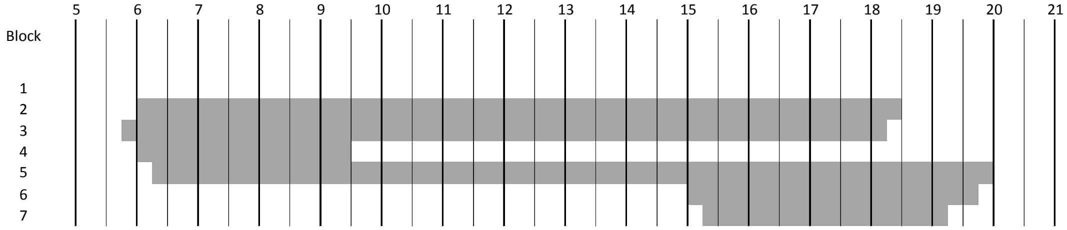
2. Rehook the Trips

The above section provided an example of how a runcut can be created using multiple pieces. But there can be limitations on the ability to create such runs (many labor agreements prohibit multipiece straights), or the operational complexity may be considered undesirable.

In this case we can throw out the philosophy that runs are cut from blocks. We can consider that runs are simply a combination of trips that comply with labor agreement rules and meet the objectives of the blocks. Many schedulers keep the blocks mostly intact out of habit. However if runs can be created as a series of trips, and the resultant blocks meet the original blocking objectives, then why take the constrained starting point of the existing blocks?

In our example the opportunity presents itself to revisit the blocks and create driver runs. In this case we only need to do some additional cutting and rehooking of blocks and don't propose to start from scratch.

So let's take the starting point of where we left off with our basic runcut—unable to create the split runs due to spread issues. The blocks are set out below.



A word of caution here. Any cutting and rehooking of blocks during the peaks runs the risk of increasing the number of vehicles required. This is not an option, under almost any circumstance. There is no reason for the runcut to result in an increase in peak vehicle numbers, regardless of the number of vehicles in operation, the labor rules, or any other constraints. So as we rehook we simply avoid cutting any blocks during the peaks.

Again we're focused on the issue of making our split runs work effectively by hooking the start of Block 4 with the finish of Block 3 and the start of Block 5 with the end of Block 2

The generic approach is to look at what happens with the blocks and link up around the edges of the peaks. Once the daytime off-peak pattern has been established (by 10 AM in this case) there is little opportunity to rehook the blocks without affecting the number of vehicles being utilized.

We could simply take the pieces generated by our previous cutting process and turn those into our new blocks. Alternatively, we could revisit the linkup, particularly around the edges of the peaks, to generate blocks that meet our runcutting requirements.

AM Blocks Example. Block 4 currently arrives at Point D at 9:18. As the service reduces from 15 to 30 minutes around this time there is no trip for it link to, and it pulls into the Garage at 9.38. Here we take the 9:18 arrival and link it to the 9:36 departure. The Block 5 9:33 arrival (currently forms the 9:36 departure) pulls into the garage instead.

PM Blocks Example. In the PM we take the 15:09 arrival on Block 2 and link it to the 15:30 Block 7 departure. This then leaves us with the remainder of Block 2, departing Point A at 15:15 and now requiring a pull out. The schedule at this time of day would then look like the following.

Original - AM

Block #			Eastbound				Westbound					
Old	New	*Pull Out*	A	B	C	D	D	C	B	A	Next Trip	*Pull In*
1		*5:46*					6:06	6:17	6:31	6:39	6:45	
2		*6:01*					6:21	6:32	6:46	6:54	7:00	
3		*5:50*	6:00	6:08	6:22	6:33	6:36	6:47	7:01	7:09	7:15	
4		*6:05*	6:15	6:23	6:37	6:48	6:51	7:02	7:16	7:24	7:30	
5		*6:20*	6:30	6:38	6:52	7:03	7:06	7:17	7:31	7:39	7:45	
1			6:45	6:53	7:07	7:18	7:21	7:32	7:46	7:54	8:00	
2			7:00	7:08	7:22	7:33	7:36	7:47	8:01	8:09	8:15	
3			7:15	7:23	7:37	7:48	7:51	8:02	8:16	8:24	8:30	
4			7:30	7:38	7:52	8:03	8:06	8:17	8:31	8:39	8:45	
5			7:45	7:53	8:07	8:18	8:21	8:32	8:46	8:54	9:00	
1			8:00	8:08	8:22	8:33	8:36	8:47	9:01	9:09		*9:19*
2			8:15	8:23	8:37	8:48	8:51	9:02	9:16	9:24	9:30	
3			8:30	8:38	8:52	9:03	9:06	9:17	9:31	9:39	10:00	
4			8:45	8:53	9:07	9:18						*9:38*
5			9:00	9:08	9:22	9:33	9:36	9:47	10:01	10:09	10:30	
2			9:30	9:38	9:52	10:03	10:06	10:17	10:31	10:39	11:00	
3			10:00	10:08	10:22	10:33	10:36	10:47	11:01	11:09	11:30	

Revised - AM

Block #			Eastbound				Westbound					
Old	New	*Pull Out*	A	B	C	D	D	C	B	A	Next Trip	*Pull In*
1		*5:46*					6:06	6:17	6:31	6:39	6:45	
2		*6:01*					6:21	6:32	6:46	6:54	7:00	
3		*5:50*	6:00	6:08	6:22	6:33	6:36	6:47	7:01	7:09	7:15	
4		*6:05*	6:15	6:23	6:37	6:48	6:51	7:02	7:16	7:24	7:30	
5		*6:20*	6:30	6:38	6:52	7:03	7:06	7:17	7:31	7:39	7:45	
1			6:45	6:53	7:07	7:18	7:21	7:32	7:46	7:54	8:00	
2			7:00	7:08	7:22	7:33	7:36	7:47	8:01	8:09	8:15	
3			7:15	7:23	7:37	7:48	7:51	8:02	8:16	8:24	8:30	
4			7:30	7:38	7:52	8:03	8:06	8:17	8:31	8:39	8:45	
5			7:45	7:53	8:07	8:18	8:21	8:32	8:46	8:54	9:00	
1			8:00	8:08	8:22	8:33	8:36	8:47	9:01	9:09		*9:19*
2			8:15	8:23	8:37	8:48	8:51	9:02	9:16	9:24	9:30	
3			8:30	8:38	8:52	9:03	9:06	9:17	9:31	9:39	10:00	
4			8:45	8:53	9:07	9:18 - - - →	9:36	9:47	10:01	10:09	10:30	
5			9:00	9:08	9:22	9:33						*9:53*
2			9:30	9:38	9:52	10:03	10:06	10:17	10:31	10:39	11:00	
3			10:00	10:08	10:22	10:33	10:36	10:47	11:01	11:09	11:30	
~~5~~	4		10:30	10:38	10:52	11:03	11:06	11:17	11:31	11:39	12:00	
2			11:00	11:08	11:22	11:33	11:36	11:47	12:01	12:09	12:30	

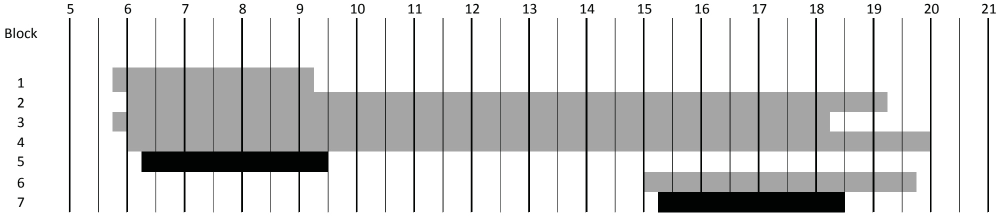
Original - PM

Block #			Eastbound				Westbound					
Old	**New**	***Pull Out***	**A**	**B**	**C**	**D**	**D**	**C**	**B**	**A**	**Next Trip**	***Pull In***
			13:00	13:08	13:22	13:33	13:36	13:47	14:01	14:09	14:30	
			13:30	13:38	13:52	14:03	14:06	14:17	14:31	14:39	15:00	
			14:00	14:08	14:22	14:33	14:36	14:47	15:01	15:09	15:15	
3			14:30	14:38	14:52	15:03	15:06	15:17	15:31	15:39	15:45	
6		*15:01*					15:21	15:32	15:46	15:54	16:00	
5			15:00	15:08	15:22	15:33	15:36	15:47	16:01	16:09	16:15	
2			15:15	15:23	15:37	15:48	15:51	16:02	16:16	16:24	16:30	
7		*15:20*	15:30	15:38	15:52	16:03	16:06	16:17	16:31	16:39	16:45	
3			15:45	15:53	16:07	16:18	16:21	16:32	16:46	16:54	17:00	
6			16:00	16:08	16:22	16:33	16:36	16:47	17:01	17:09	17:15	
5			16:15	16:23	16:37	16:48	16:51	17:02	17:16	17:24	17:30	
2			16:30	16:38	16:52	17:03	17:06	17:17	17:31	17:39	17:45	
7			16:45	16:53	17:07	17:18	17:21	17:32	17:46	17:54	18:00	
3			17:00	17:08	17:22	17:33	17:36	17:47	18:01	18:09		*18:19*
6			17:15	17:23	17:37	17:48	17:51	18:02	18:16	18:24	18:30	
5			17:30	17:38	17:52	18:03	18:06	18:17	18:31	18:39	19:00	
2			17:45	17:53	18:07	18:18						*18:38*
7			18:00	18:08	18:22	18:33	18:36	18:47	19:01	19:09		*19:19*
6			18:30	18:38	18:52	19:03	19:06	19:17	19:31	19:39		*19:49*
5			19:00	19:08	19:22	19:33						*19:53*

Revised - PM

Block #			Eastbound				Westbound					
Old	**New**	***Pull Out***	**A**	**B**	**C**	**D**	**D**	**C**	**B**	**A**	**Next Trip**	***Pull In***
			13:00	13:08	13:22	13:33	13:36	13:47	14:01	14:09	14:30	
			13:30	13:38	13:52	14:03	14:06	14:17	14:31	14:39	15:00	
			14:00	14:08	14:22	14:33	14:36	14:47	15:01	15:09	15:15	
3			14:30	14:38	14:52	15:03	15:06	15:17	15:31	15:39	15:45	
6		*15:01*					15:21	15:32	15:46	15:54	16:00	
5			15:00	15:08	15:22	15:33	15:36	15:47	16:01	16:09	16:15	
~~2~~	7	15:05	15:15	15:23	15:37	15:48	15:51	16:02	16:16	16:24	16:30	
~~7~~	2	~~*15:20*~~	15:30	15:38	15:52	16:03	16:06	16:17	16:31	16:39	16:45	
3			15:45	15:53	16:07	16:18	16:21	16:32	16:46	16:54	17:00	
6			16:00	16:08	16:22	16:33	16:36	16:47	17:01	17:09	17:15	
5			16:15	16:23	16:37	16:48	16:51	17:02	17:16	17:24	17:30	
~~2~~	7		16:30	16:38	16:52	17:03	17:06	17:17	17:31	17:39	17:45	
~~7~~	2		16:45	16:53	17:07	17:18	17:21	17:32	17:46	17:54	18:00	
3			17:00	17:08	17:22	17:33	17:36	17:47	18:01	18:09		*18:19*
6			17:15	17:23	17:37	17:48	17:51	18:02	18:16	18:24	18:30	
5			17:30	17:38	17:52	18:03	18:06	18:17	18:31	18:39	19:00	
~~2~~	7		17:45	17:53	18:07	18:18						*18:38*

The blocks are then updated in the diagram to show the new Blocks 2 and 7 (the PM change) and Blocks 4 and 5 (the AM change). The end result is two peak-only blocks (Blocks 5 and 7) that can form a split run within the spread requirements.



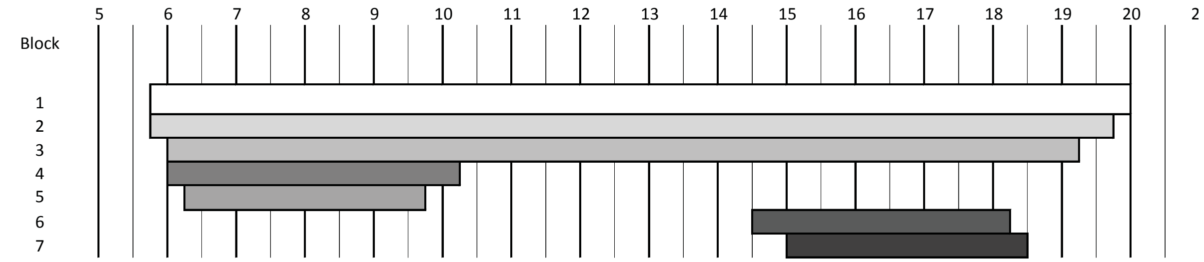
We then repeat the process to generate two more blocks (based on the start of Block 4 and the end of Block 3) that will allow another split run to be created from peak blocks. The process is the same. Looking at the above diagram we simply want to have Block 4 finish after the AM Peak and have Block 1 operate all day. In the PM Peak we want to have Block 3 (the earliest finish) be a standalone PM Block, with Block 6 taking the rest of Block 3's day. One must be extremely careful during this process to keep track of the block numbers and changes through what is an iterative process.

After making the changes as described above, the run guide is updated, and the blocks and runs are renumbered. The figures below provide the outputs of the process with a new runcut solution. The solution is provided including the finalized headway sheet (with revised block numbers and pull ins/pill outs), blocking diagram, and run guide.

Revised blocks for RunCut

ROUTE 97 Broad Street
DAY Weekday

		Eastbound				**Westbound**					
Block #	***Pull Out***	**A**	**B**	**C**	**D**	**D**	**C**	**B**	**A**	**Next Trip**	***Pull In***
1	*5:46*					6:06	6:17	6:31	6:39	6:45	
3	*6:01*					6:21	6:32	6:46	6:54	7:00	
2	*5:50*	6:00	6:08	6:22	6:33	6:36	6:47	7:01	7:09	7:15	
4	*6:05*	6:15	6:23	6:37	6:48	6:51	7:02	7:16	7:24	7:30	
5	*6:20*	6:30	6:38	6:52	7:03	7:06	7:17	7:31	7:39	7:45	
1		6:45	6:53	7:07	7:18	7:21	7:32	7:46	7:54	8:00	
3		7:00	7:08	7:22	7:33	7:36	7:47	8:01	8:09	8:15	
2		7:15	7:23	7:37	7:48	7:51	8:02	8:16	8:24	8:30	
4		7:30	7:38	7:52	8:03	8:06	8:17	8:31	8:39	8:45	
5		7:45	7:53	8:07	8:18	8:21	8:32	8:46	8:54	9:00	
1		8:00	8:08	8:22	8:33	8:36	8:47	9:01	9:09	10:30	
3		8:15	8:23	8:37	8:48	8:51	9:02	9:16	9:24	9:30	
2		8:30	8:38	8:52	9:03	9:06	9:17	9:31	9:39	10:00	
4		8:45	8:53	9:07	9:18	9:36	9:47	10:01	10:09		*10:19*
5		9:00	9:08	9:22	9:33						*9:53*
3		9:30	9:38	9:52	10:03	10:06	10:17	10:31	10:39	11:00	
2		10:00	10:08	10:22	10:33	10:36	10:47	11:01	11:09	11:30	
1		10:30	10:38	10:52	11:03	11:06	11:17	11:31	11:39	12:00	
3		11:00	11:08	11:22	11:33	11:36	11:47	12:01	12:09	12:30	
2		11:30	11:38	11:52	12:03	12:06	12:17	12:31	12:39	13:00	
1		12:00	12:08	12:22	12:33	12:36	12:47	13:01	13:09	13:30	
3		12:30	12:38	12:52	13:03	13:06	13:17	13:31	13:39	14:00	
2		13:00	13:08	13:22	13:33	13:36	13:47	14:01	14:09	14:30	
1		13:30	13:38	13:52	14:03	14:06	14:17	14:31	14:39	15:00	
3		14:00	14:08	14:22	14:33	14:36	14:47	15:01	15:09	15:30	
2		14:30	14:38	14:52	15:03	15:21	15:32	15:46	15:54	16:00	
1		15:00	15:08	15:22	15:33	15:36	15:47	16:01	16:09	16:15	
3		15:30	15:38	15:52	16:03	16:06	16:17	16:31	16:39	16:45	
2		16:00	16:08	16:22	16:33	16:36	16:47	17:01	17:09	17:15	
1		16:15	16:23	16:37	16:48	16:51	17:02	17:16	17:24	17:30	
3		16:45	16:53	17:07	17:18	17:21	17:32	17:46	17:54	18:00	
2		17:15	17:23	17:37	17:48	17:51	18:02	18:16	18:24	18:30	
1		17:30	17:38	17:52	18:03	18:06	18:17	18:31	18:39	19:00	
3		18:00	18:08	18:22	18:33	18:36	18:47	19:01	19:09		*19:19*
2		18:30	18:38	18:52	19:03	19:06	19:17	19:31	19:39		*19:49*
1		19:00	19:08	19:22	19:33						*19:53*



Completed Runcut - Blocks Re-Hooked

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Paid Break	Travel Hours	Total Work Hours	Spread	Make-up	Overtime	Spread Penalty	Paid Hours	Pay/ Plat
				Time	Place	Type	Time	Place	Type												
101	Str	1	5:31	5:46	Garage	Pull	13:09	A	Street	13:34	7:23	0:30		0:10	8:03	8:03	0:00	0:01:30	0:00:00	8:04:30	1.094
102	Str	1	12:44	13:09	A	Street	19:53	Garage	Pull	20:08	6:44	0:30		0:10	7:24	7:24	0:36	0:00:00	0:00:00	8:00:00	1.188
103	Str	2	5:35	5:50	Garage	Pull	12:39	A	Street	13:04	6:49	0:30		0:10	7:29	7:29	0:31	0:00:00	0:00:00	8:00:00	1.174
104	Str	2	12:14	12:39	A	Street	19:49	Garage	Pull	20:04	7:10	0:30		0:10	7:50	7:50	0:10	0:00:00	0:00:00	8:00:00	1.116
105	Str	3	5:46	6:01	Garage	Pull	12:09	A	Street	12:34	6:08	0:30		0:10	6:48	6:48	1:12	0:00:00	0:00:00	8:00:00	1.304
106	Str	3	11:44	12:09	A	Street	19:19	Garage	Pull	19:34	7:10	0:30		0:10	7:50	7:50	0:10	0:00:00	0:00:00	8:00:00	1.116
107	Spl	4	5:50	6:05	Garage	Pull	10:19	Garage	Pull	10:24	7:47	0:50		0:00	8:37	12:44	0:00	0:18:30	1:22:00	10:17:30	1.322
		6	14:31	14:46	Garage	Pull	18:19	Garage	Pull	18:34											
108	Spl	5	6:05	6:20	Garage	Pull	9:53	Garage	Pull	9:58	7:06	0:50		0:00	7:56	12:48	0:04	0:00:00	1:24:00	9:24:00	1.324
		7	14:50	15:05	Garage	Pull	18:38	Garage	Pull	18:53											
											56:17	**4:40**	**0:00**	**1:00**	**61:57**		**2:43**	**0:20**	**2:46**	**67:46**	**1.204**

In terms of efficiencies this solution is the lowest cost of the three developed thus far—a total of 67:46 paid time compared to 68:27 and 68:37 for the previous two solutions. It retains the six straight runs and four split runs of the previous solution, ensuring manpower requirements are minimized.

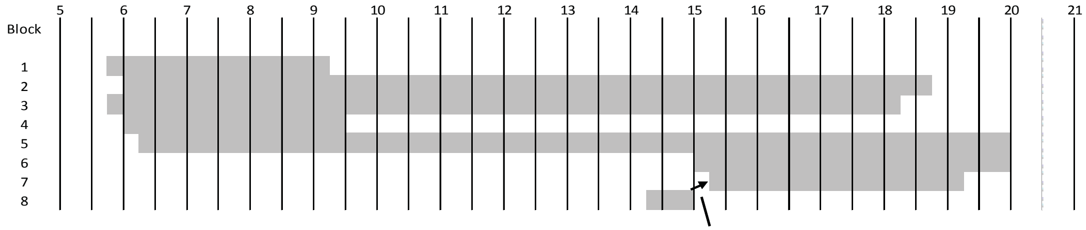
Operationally the outcome is a completed set of legal runs, with the two full-time splits, and with no multipiece or tight connection issues. In fact Block 1 could run an additional round trip departing Point A at 9:15 and Point D at 9:51—thus keeping the 15-minute frequency out for an additional 30 minutes with no labor cost implications. This is a classic example of benefits obtained when the runcut and blocking interaction is iterative in nature.

Before this (or any) solution is completed we must go back and recreate the car "runs," ensuring that we know when the car(s) are used, who will be driving them, and when they arrive and depart the garage.

The above example allowed us to work through some reasonably straightforward examples of how revisiting the blocks can assist in producing a better runcut solution. But there are numerous other situations where revisiting the blocks can enhance the runcut solution. Some of these are discussed below.

Rehooking a School Extra

In some transit systems school trips are blocked separately. The reasons for this are numerous, and for now we simply accept that our blocks may have such occurrences. Usually this will be evident as soon as we look at our block graph. The example below will show, again without needing to look at numbers or details, a block that could potentially be rehooked during the runcut.



BLOCKS 7 AND 8

Tip Exercise caution when hooking school trips to regular daily runs. School schedules are often variable with schedule changes that may not be compatible with run assignments.

Here we have added a new block (block 8) to cover a short school trip. It then pulls back into the garage. In this example the block has only 15 minutes of revenue time but 45 minutes of platform time—one short school trip with a garage pull either side. By rehooking the blocks to add this trip to the front of Block 7 we could potentially create a more efficient run and even reduce total platform time. The reduction would be achieved by removing the pull in on Block 8 and pull out on Block 7, and replacing them with a direct deadhead between the end of Block 8 and the start of Block 7, and possibly some layover. Of course this would only be achievable if there is enough time for the bus to get from where the school tripper ends to the starting point of Block 7. However if this achievable we are likely to produce a better runcut solution, and deal effectively with a block that would otherwise be difficult to assign.

But should we do this? It could depend on several factors.

1. Is it agency policy to keep school trippers separate? Sometimes school trips are offered as additional overtime and are intentionally kept separate.

2. Often school trips are kept separate to deal with changing bell times—for example, if the school gets out 30 minutes later on one day per week our nice rehook suddenly does not work on that day.

You will need to consider such questions and understand how your agency approaches such issues. If the runcutter is not the same person who develops schedules and blocks at your agency, it is important to maintain good communication between all to understand the intent behind how the blocks were created. As with many aspects of scheduling the decision includes some form of value judgment and needs to be informed by as much relevant information as possible.

If in the end such changes are made, the blocking sheets, run guides, and any other documents need to be updated accordingly.

A Recap

In working through these examples we have actually dealt with many of the important concepts relating to runcutting. Let's list a few below:

- **Types of runs.** The basic run types, which are most suitable in specific cases, and some of the impacts of each.
- **Relief types.** The types of reliefs that can be used and how to create runs with those relief types.
- **Cutting pieces.** How we decide when and where to cut pieces that will be used to form runs.
- **Matching pieces.** How we match pieces (in our examples, of split runs) to create full runs.
- **Shifting pieces.** Changing which relief opportunities we used to cut pieces to create the most efficient and effective overall solution.
- **Reliefs.** How to choose which relief opportunities to cut pieces.
- **Revisiting blocks.** Some instances where we may want to rehook some blocks to achieve better runcut outcomes.
- **Improving runcut efficiencies.** Looking at combinations of the above methods to reduce the overall runcut cost.

Congratulations, you're now doing most of the things that sophisticated computerized systems attempt to mimic! Initially we presented runcutting as a complex mathematical problem with myriad inputs, requirements, preferences, and outcomes. However in working through the above examples we have actually considered much of what is required to produce even more complex runcuts.

LEVEL 2

End of Intermediate Runcutting.

The Advanced Section of Runcutting continues on the next page.

To jump to Rostering, go to page 6-1.

5.3 Advanced Runcutting

LEVEL 3

In the previous sections we have developed runcut solutions for a scenario containing a relatively basic schedule, simple work rules, and minimal constraints. The Line 97 example is of course simple in that it involves one route, one garage, and one relief location (using one type of relief). In those examples, the work rules used were limited to a basic set of hard rules, with no implied limits based on preferences or unwritten practices. The reality of scheduling is that many situations presented to the scheduler are more complex than this, with multiples in many of these categories—multiple routes, garages, relief locations, and types, for example.

However the Line 97 schedule presents many constraints that often do not exist in many runcuts. The scale or size of the runcut is a significant factor in the difficulty of creating a solution. Cutting just a single run often results in a less optimal solution than cutting an entire system. However, contrary to many expectations, this is often an inversely proportional relationship, i.e., the larger the runcut the easier it is to find a solution!

Looking back at any of the block diagrams for the Line 97 runcuts we see limited options to cut pieces. For example there were only two shorter peak blocks in each peak, and those blocks did not allow us to form runs within the 13-hour spread limitation. In another situation, with 40 or 50 vehicles we might have had a range of shorter blocks to choose appropriate starts and finishes to match pieces into legal split runs.

For this reason there is less need to work through further examples of larger problems. Just simply apply the same approaches, philosophies, and tools to dealing with larger runcuts. In this section we will look less at the mechanics of the runcuts (although there will be numerous examples), and consider more of the discussion around runcut approaches, and how more difficult issues can be resolved. The later parts of this section revolve around a discussion of some key policy issues relating to runcuts.

Larger or more complex problems can add the following elements to the examples we have worked through to this point:

Volume of trips, blocks, and routes

If runs are cut at a route level (i.e., each run only operates on one route) the approach to cutting a route with more service or longer service span is exactly the same as in the previous examples. There will of course be increased options, more runs, additional pieces, etc., but the approach remains the same.

Additional Garages

Creating runs for multiple-garage solutions adds complexity to the scheduler's task, both at a blocking and runcutting level. Where there are multiple garages, another level of consideration is required:

- At which garage should the piece start/endt?
- Can the block be adjusted to change garages?
- What are the travel times between the relief locations and each garage?
- Can meals occur at a different garage than the "home" garage for a run?
- Are compatible bus types assigned to each garage?

While these issues do add complexity to the runcut process, it tends to be more an issue of increased options rather than placing constraints on the scheduler. However in considering those options the impact of optimizing start/end locations is critical to minimizing overall deadheading or travelling costs. Two key considerations are:

- Vehicles to be balanced at the start and end of the day, i.e., the same number of vehicles must pull out of a garage that pull in at the end of the day
- Generally operators must start and end their work day at the same garage

These two factors must be taken into account, along with the considerations noted above, when undertaking multi-garage runcutting.

Additional Relief Types and Locations

Our Line 97 example had one relief location and one method of traveling to that location. In many cases routes will have multiple relief locations and possibly other methods of travel. Additional relief opportunities actually only help to make the problem more readily solvable—through presenting the scheduler with more options for cutting pieces.

The extension of concepts for relief types is discussed in more depth later in this section.

More Complex Work Rules

Work rules present the most difficult and constraining factor in runcutting and also represent the most variability from one operator to another. Earlier sections of this manual have already discussed concepts of hard rules, soft rules, constraints, and practices. At times these can contradict each other, or be difficult to understand or explain.

Take the work rules relating to meal breaks for one transit system:

> *At least one of the following constraints must be met in straight runs over 8 hours:*
>
> - *1 x 20 minute break and 1 x 10 minute break; or*
> - *3 x 15 minute breaks; or*
> - *60 minutes total layover (15% of runs maximum)*

The agreement states that not only must one of these be scheduled in each run, but also that 80% must be achieved in actual operation. In actuality, virtually all scheduled break requirements are expected to be achieved in operations.

Runs are further limited by the requirement that no more than 23% of runs can involve a vehicle change. This limits options to create multipiece runs to deal with the breaks.

Just reading and understanding these interrelated work rules is a complex task. And these constraints apply to only a small part of the overall work rules at the agency (i.e., the meal breaks).

The limitations applied to scheduling processes by more constrained work rules or practices present the biggest challenge to the scheduler. This manual cannot even begin to attempt to explain myriad work rules and practices adopted or applied by transit systems. We have noted some of the "typical" kinds of rules applied and discussed how to create runs with these rules in mind.

We would simply recommend that strong consideration is given to work rules when scheduling, and that the rules be appropriately applied. By "appropriate" here, we mean as intended by the agency to fit within the overall agency's objectives and policies.

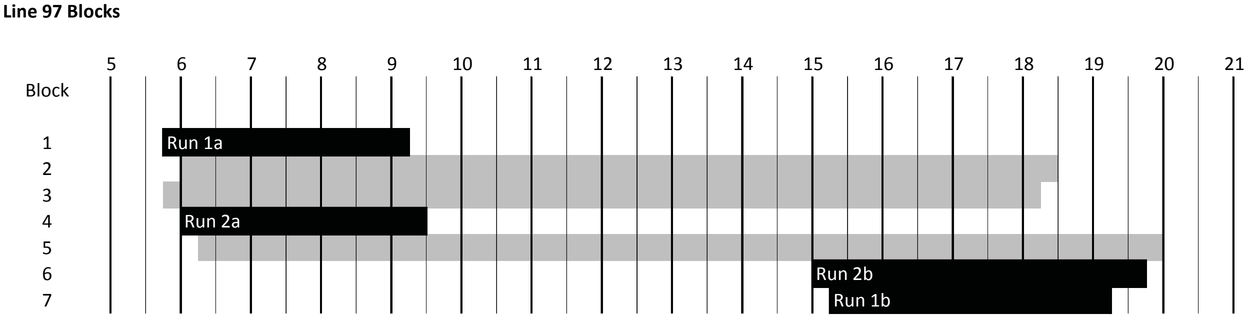
Using a computerized system actually provides some good checks and balances in this respect, as the scheduler must actually write down the rules, constraints, limits, and preferences. These must be succinctly defined and expressly stated for the system to be able to create legal runs. When using other scheduling techniques, this approach should be mimicked—write down the specific rules, not in the words of the labor agreement, but as input into runcutting. Summarize these rules or practices and circulate them to gain wider approval.

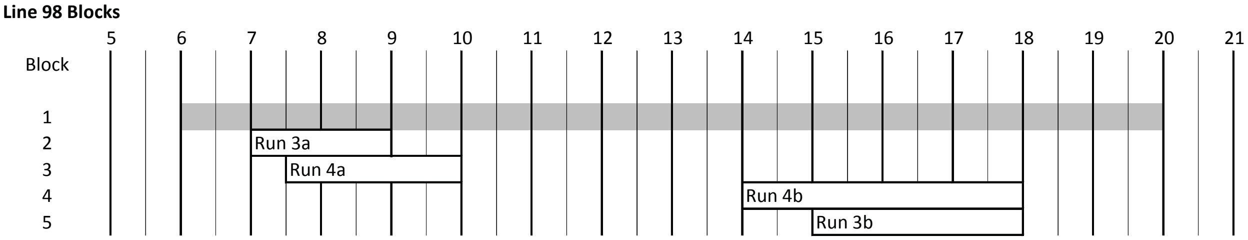
On the other hand, the computer is not as good at making nuanced judgments as a human scheduler can be. Only an expert scheduler knows which rules can be "bent" and how often—the computer will "do as you say" but will not make the complex trade-offs and judgments that an experienced scheduler can make. This is why, even at properties that utilize up-to-date computerized scheduling packages, an experienced scheduler should always review the end result and see if further optimization could take place with a few reasonable adjustments.

Runcutting Multiple Routes

The number of variables increases dramatically when cutting multiple routes. The classic example of multiple-route scheduling involves hooking together peak blocks to form split runs. In our original Line 97 example, we had four standalone peak blocks that had a spread too long to fit within spread limits, or at least to avoid incurring high spread premiums.

If we add a second route into the runcutting mix we can see some potential for immediate benefits, as per the diagram below:



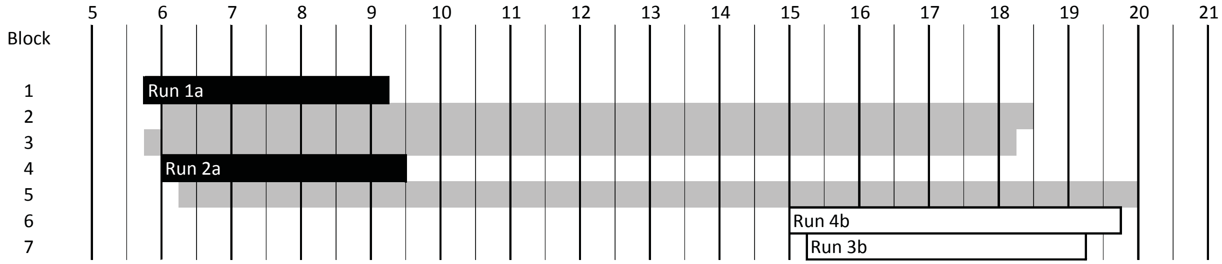


On Line 98 we have a much shorter peak, with 7:00 and 7:30 starts, and two 18:00 finishes. If Line 98 was blocked standalone we would have two split runs (the white Runs 3 and 4) with 6:45 and 7:15 report times, and 18:15 sign off times. At the same time we have split runs on Line 97 that are either illegal (spread too long) or have long spreads with high premium paid.

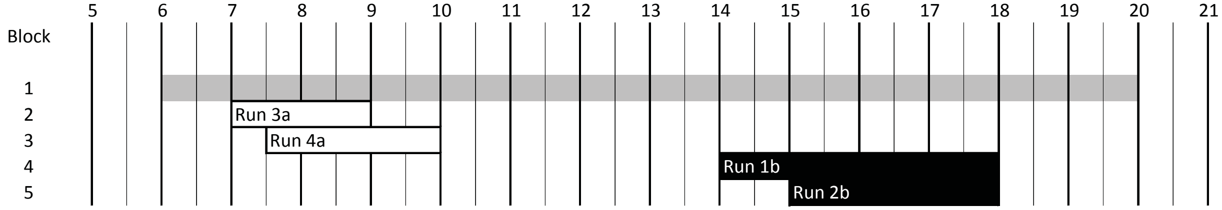
If we matched the late starts on Line 98 with the late finishes on Line 97, and the early starts on Line 97 with the early finishes on Line 98, we get four legal split runs with a reduction in total spread premium.

The following diagram represents the newly created multiroute split runs.

Line 97 Blocks



Line 98 Blocks



This is a simple example where the pieces matched easily. In practice such outcomes are not always the case. However the concept and approach remains the same—that the introduction of multiple routes allows the potential for increased options and better runcuts. As with larger problems, the issue is one of size, and the more options present more potential solutions.

Trips, Blocks, and Runs

In our earlier examples, we learned that it is sometimes possible to make small changes to blocks to improve the runcut solution. But in those examples, the changes made were only minor, affecting only two or three blocks.

Let's now go back to a statement made in a preceding section—that the runs are, in effect, a group of trips that form an operator's work day. Often schedulers limit the ability to produce effective runcuts by assuming the blocks are fixed, or by limiting changes

Note here that to some extent we are playing with fire. The primary reason to begin runcutting with a set of blocks is that blocking is designed to minimize the number of vehicles required to operate a given schedule. By essentially throwing out the blocks and starting with a list of trips, we are optimizing for driver hours, but not necessarily for peak vehicles. Peak vehicle availability is often fixed at a transit operator and may be an even more rigid limitation than the number of driver hours.

Tip Under no circumstance should the runcut result in increased peak vehicle requirements over the blocking solution.

multipiece runs

Runs made up of pieces from multiple blocks. In most cases, split runs are inherently multipiece runs. But either half of a split run could itself could have multiple pieces, cut from multiple blocks.

Runcutting Multipiece Runs

Many transit systems avoid **multipiece runs** and many labor agreements forbid or constrain them. The reason appears to be primarily one of simplicity and control. A set of runs comprised of long blocks cut into straights, and peak blocks matched to splits (or assigned to part-time runs) is a simple and coherent runcut option.

However as we have discussed and seen in our examples, the limitations of relief opportunities make it difficult to cut straight runs, and/or match pieces into split runs, in an optimized manner. We can go back and reconsider our definition of "optimized" here. Our Line 97 example was possibly "optimal" with the constraints placed on it. But was it the "optimal" solution in terms of minimized paid hours for the given set of trips? The answer is almost certainly not.

A primary aim of creating more and smaller pieces is to be able to combine and match them into runs that better improve the runcut solution. This can potentially result in reduced overall cost and a lower pay-to-platform ratio.

The pieces used in multipiece runs can be cut at the same relief location, or perhaps at different locations with a travel in between. The aim is to create pieces of work that can be best matched together across the whole runcut. In the previous section we did this to improve our split runs and then rehooked the blocks to avoid the "multipiece run" name. But in effect that is what happened—we created runs with multiple pieces to improve the runcut solution.

We are treading here on some prevailing scheduling theory in that multipiece runs are often frowned upon as "bad" or "wasteful." This can be true for one or two runs, particularly if there is a paid break or long travel between the pieces. However in the context of the total runcut the creation of some smaller pieces can provide significantly enhanced overall efficiencies.

So how do multipiece runs work? The concept is simple—cut smaller pieces and match them together to form runs, in much the same way that we matched pieces together for split runs in earlier examples. But in this case we are trying to match pieces with smaller breaks (so as not to incur paid break time), while meeting other runcut objectives.

The advent of computerized scheduling makes it possible to test different types of runcutting solutions. These systems allow run types such as multipiece runs (of any sort—straight, split, part-time) to be tested and reviewed, within an overall optimized runcut. One reason multipiece runs are not always embraced is the sheer complexity they cause for schedulers. If multiple piece runs are allowed, the potential number of pieces and cuts increases dramatically.

Pull Reliefs and Multipiece Runs

We can go back to our example in the intermediate section (***"Rehook the Trips"***) to see multipiece runs with pull reliefs which were then rehooked to provide updated blocks. A key feature of this example was that the blocks were rehooked outside the peak periods. This is a very important point. Allowing runcutting processes to rehook trips during the peaks (when peak vehicle requirements are defined) can result in increased vehicle requirements. Outside of the peak, the use of pull reliefs can increase vehicle needs with little consequence (an exception being if you have a very low peak-to-base ratio, in which case off-peak vehicle increases can affect other operational requirements such as availability of vehicles for maintenance). When using computerized systems, this requirement must be carefully monitored, as the runcut modules at times fail to consider the cost of peak vehicles in their cost optimization process.

The potential costing impacts of pull reliefs need to be carefully considered by the scheduler before any widespread application. Greater use of pull reliefs is almost guaranteed to increase vehicle mileage, often at the expense of cheaper car mileage. As noted, the evaluation of use of different relief types can be undertaken quickly and effectively through use of computerized scheduling systems.

If multipiece runs have been created, using pull reliefs, it usually is a simple matter of recreating the blocks after the runs have been created. Again, be careful not to overlook some considerations taken into account by the scheduler when blocking such as:

- Congestion/capacity at terminals;
- Vehicle type limitations;
- Reliability on certain routes;
- Interlining limitations; and
- Maintaining adequate recovery time.

Runcutting for Meals

So far, our examples have included only three types of run—straight runs, split runs, and part-time runs. Our straight runs have been one-piece runs, and the splits have had a break back at the garage.

Many agencies now have labor rules mandating some form of operator breaks. In many parts of the United States new rules mandating meal and rest break requirements are being developed and implemented. Rules relating to meal breaks can differ significantly in complexity and in how they affect efficiencies. These may change from one transit agency to another.

Tip Many agencies struggle with providing meal breaks, due to the increased complexity and potential constraints. However, meal breaks, if the right labor rules exist, need not add significantly to the cost of operating service. This holds true in particular where meal breaks are unpaid and can be taken at the terminal rather than returning to the garage.

The types of breaks required may include:

- **Minimum layover requirements.** Sometimes expressed as a percentage of layover time during a work day, or at least one layover of x minutes.
- **Stipulated meal breaks.** Meal breaks come in many forms with varying requirements. The breaks may be paid or unpaid, taken back at the garage or at relief locations (or in-vehicle), may have minimum/maximum lengths (above the maximum length the run typically becomes a split) , and may be required to be spaced at certain times during the work day.
- **Other rest breaks.** These may be required in addition to scheduled meal breaks (such as one 10-minute layover every two hours).

Many agencies view meal break requirements as immediately resulting in cost increases. However, as we will see as we explore some of the detail, this is not necessarily the case. In many parts of the world transit systems operate with meal break requirements while creating extremely efficient run cuts.

Depending upon the combination of rule requirements, the scheduling of meal breaks can make the runcutting task significantly more complex. If a piece of work can only be five hours long, for example, it means that all straight runs must have at least two pieces. This doubles the number of reliefs that must be considered, exponentially increasing the mathematical complexity of the problem to be solved.

In the case of minimum layover requirements, it may be possible to build the blocks with these already built in. In our Line 97 example we built the schedule with 21 minutes of layover at Point A. When we hooked our trips into blocks, we considered that breaks might be required. If we go back and review our runs in detail we will see that the straight runs (those that are most likely to require meal or rest breaks) have a 20-minute break every 90 minutes. In this case our thinking ahead allowed the requirement to be met.

But what happens when there is a more complex or restrictive rule—a typical meal break requirement such as “the operator must have a meal break of between 30 and 60 minutes, between the second and fifth hour”? The break may be paid or unpaid; in this case we will assume it is unpaid. If we assume everything else remains unchanged we can go back and rebuild our runs.

At this stage we can consider two potential approaches to runcutting to meet the meal break requirements. The first involves cutting longer pieces, across multiple vehicles, and assigning operators two pieces of work in a run. The second involves operator drop-backs at terminals.

Approach 1: Recutting the Runs

This approach to cutting the runs changes the mechanics of the process significantly, since we now must have run "portions" (the work either side of a meal break) no longer than five hours. And those pieces must be less than five hours, given that we will possibly need to add travel time and report time to the actual platform time of the piece.

In this case we'll go back and use our original Line 97 blocks and assume all street reliefs at Point A once again. We will assume that meal break must be taken back at the garage, requiring travels to and from the depot. We will also assume the meal break will also be unpaid. As we will discuss later, these are two key factors in the cost impacts of meal breaks. In this example we have taken a less restrictive view of one factor (paid meals) and a more restrictive view as to where meal breaks can be taken (in this case at the garage and not at trip terminals).

Where do we start? As always the scheduler should make some macro observations about the number of runs (by type), the nature of the blocks, and potential pieces.

We know from the previous examples that we had eight full-time runs. However with 54 hours of platform time we could be looking to create as few as seven runs. And the runcuts produced had almost three hours of guarantee due to the runs being generally shorter than we would have preferred.

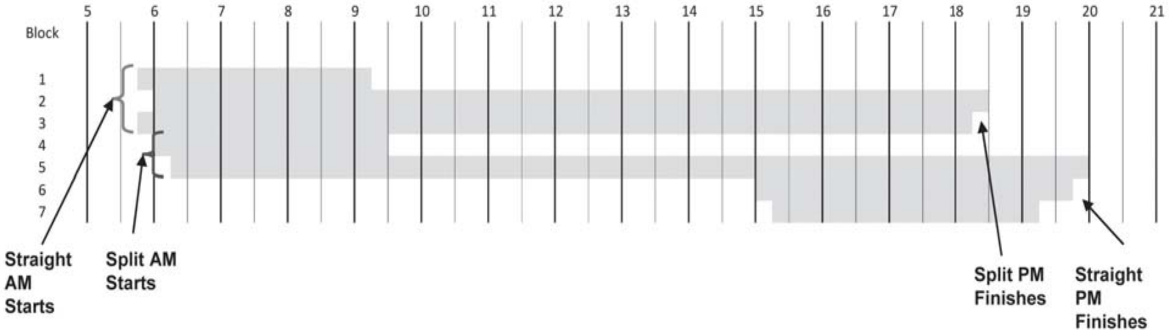
We also need to think about how many pieces we will cut—we will assume all runs are now two pieces for a straight or split, and one piece for a part-time run. If we are looking for eight-hour runs, and a piece cannot be more than five hours, that means we'd ideally like all pieces to be between three and five hours. Before starting to create pieces or runs, we should review the blocks and consider how often we will need to cut. This is shown simply below.

Block	Length	Pieces
1	3:33	1
2	12:37	3
3	12:29	3
4	3:33	1
5	13:33	3
6	4:48	1
7	3:59	1
Total	54:31	13
Average		4:11

Tip As a starting point, look to the blocks with the earliest starts as opportunities for straight runs, and blocks with later starts and early finishes as possibilities for split runs.

The table gives us a very rough idea of the number of pieces we are aiming for and the average length of each piece. The actual number of work pieces and run length will be determined in large part by the opportunities we have for reliefs. The number of pieces will also be affected by the need to combine pieces into straight runs. The odd number of pieces suggests we may end up with either a part-time run or a longer straight run with more than two pieces (and possibly two meals). But for now it is enough to know how many pieces and runs we are aiming for. So the 13-piece indication is only an approximation at this point and could change.

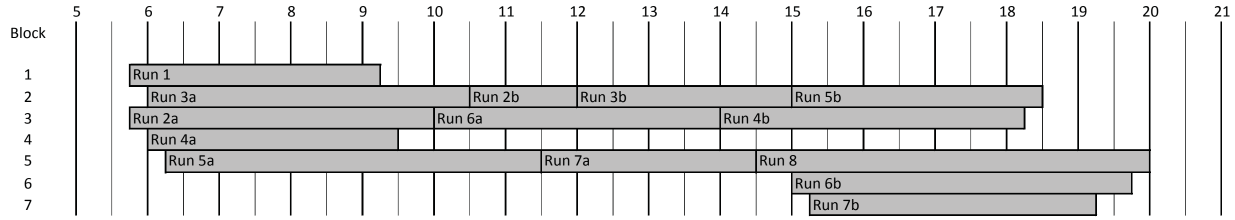
A general rule of thumb is to begin with the early start times as candidates for straight runs, leaving the splits to be the later starts and earlier finishes. This minimizes spread premium costs and is a generally accepted preference for operators. If we review our blocks again this means that we are looking for the starts of blocks 1, 2, and 3 to be the first piece of our straight runs. In the PM we want our early finishes to be the splits and later finishes to be PM Straights.



In effect we are ensuring our shorter splits, with starts at 6:05 (Block 4) and 6:20 (Block 5), and finishes at 18:19 (Block 3) and 18:38 (Block 2). This is the same matching process we undertook when rehooking blocks to arrive at our preferred splits, with minimized spread premium, in the earlier example.

In effect we have already created the split pieces. We just need to know when to finish the two AM pieces and start the two PM pieces. The finishing time of Block 4 is mandated by the fact that it is a smaller peak-only block. So we assume Block 4 is the first half of one of our split runs. To minimize our spreads we want to match this with the piece on Block 3 ending at 18:19. Assuming we are looking for around an 8-hour run, this dictates a cut at before 14:30.

A process of cutting and matching is then undertaken to create and match pieces to form legal and efficient runs. Again we turn to a graphical representation of the runs to provide an overview of how the blocks have been cut into pieces. Pieces with the same run number (e.g., run 5 is pieces of Blocks 3 and 6) form a Straight Run (Run 6—see Run guide below).



As the diagram depicts, the additional pieces required by creating runs with meal breaks adds significant complexity. The process requires consideration of numerous combinations of potential pieces. However some basic rules can be applied:

- Look at the start and end pieces initially to provide an idea of the pieces and runs. Working forward from the block starts (to a maximum of 5 hours) and backwards from block ends will provide an indication of how many of each type of run will be required.
- Avoid cutting for meals during the peaks where possible, since this in effect means two operators are covering the one peak.
- Cut the AM straight pieces as the early starts.
- PM straight pieces should generally be as long as possible to ensure operators can cover both the PM peak and late night services. This of course depends on how late the service runs. In this case the night service is minimal.
- Split pieces should be cut with spread limitations in mind.
- The number of straight runs will be a function of the level of early, midday, and night service levels. With only three midday blocks in our example, and no night service, the opportunities to cut straight runs are reduced.

Now let’s move on to the solution. The run guide is again provided, this time with some additional information to explain the straight runs.

There are eight total runs. Of these, we have four straights, two splits, and two part-time. Note the total paid time has increased from 67:46 in our previous solution to 69:06. However this is probably a good outcome given the additional travel time required to have all straight runs return to the depot for meals (in effect adding an additional 1:20 of time into the runs).

Meal Breaks - Completed Run Cut

Run #	Type	Block #	Piece Start	Start			End			Piece End	Break Length	Piece Hours	Plat Hours	Report Hours	Travel Hours	Paid Break	Total Hours	Spread	Guarantee	Overtime	Spread Penalty	Paid Hours	Pay/ Plat
				Time	Place	Type	Time	Place	Type														
1	Pt	1	5:31	5:46	Garage	Pull	9:19	Garage	Pull	9:34		4:03	3:33	0:30	0:00		4:03	4:03	0:00	0:00	0:00	4:03	1.141
2	Str-a	3 2	5:35 10:29	5:50 10:39	Garage A	Pull Street	9:39 12:09	A A	Street Street	9:49 12:34	0:40	4:14 2:05	5:19	0:30	0:30	0:00	6:19	6:59	1:41	0:00	0:00	8:00	1.505
3	Str-a	2 2	5:46 11:59	6:01 12:09	Garage A	Pull Street	10:39 15:09	A A	Street Street	10:49 15:34	1:10	5:03 3:35	7:38	0:30	0:30	0:10	8:48	9:48	0:00	0:24	0:00	9:12	1.205
4	Spl	4 3	5:50 13:44	6:05 14:09	Garage A	Pull Street	9:38 18:19	Garage Garage	Pull Pull	9:43 18:34	4:01	3:53 4:50	7:43	0:50	0:10		8:43	12:44	0:00	0:21	1:22	10:26	1.353
5	Spl	5 2	6:05 14:44	6:20 15:09	Garage A	Pull Street	11:39 18:38	A Garage	Street Pull	11:54 18:53	2:50	5:49 4:09	8:48	0:50	0:20		9:58	12:48	0:00	0:59	1:24	12:21	1.403
6	Str-p	3 6	9:14 15:01	9:39 15:01	A Garage	Street Pull	14:09 19:49	A Garage	Street Pull	14:19 20:04	0:42	5:05 5:03	9:18	0:30	0:20	0:00	10:08	10:50	0:00	1:04	0:00	11:12	1.204
7	Str-p	5 7	11:14 15:20	11:39 15:20	A Garage	Street Pull	14:39 19:19	A Garage	Street Pull	14:49 19:34	0:31	3:35 4:14	6:59	0:30	0:20	0:00	7:49	8:20	0:00	0:00	0:00	7:49	1.119
8	Pt	5	14:14	14:39	A	Street	19:53	Garage	Pull	20:08		5:54	5:14	0:30	0:10		5:54	5:54	0:00	0:00	0:00	5:54	1.127
													54:32	**4:40**	**2:20**	**0:10**	**61:42**		**1:41**	**2:48**	**2:46**	**68:57**	**1.265**

Is this a “good” runcut? The results can be compared to our most recent solution.

Runcut Comparison

	Solution 1			**Solution 2**		
Straight Runs	6	75%		4	50%	
Split Runs	2	25%		2	25%	
Total FT Runs	8			6		
Part Time Runs	0	0%		2	25%	
Total Operators Required	8			8		
Hours Breakdown	Total	Avg	%	Total	Avg	%
Platform	56.3	7.0	91%	54.5	6.8	88%
Report	4.7	0.6	8%	4.7	0.6	8%
Travel	1.0	0.1	2%	2.3	0.3	4%
Paid Break	0.0	0.0	0%	0.2	0.0	0%
Total Work Hours	62.0	7.8		61.7	7.7	
Penalties						
Spread	2.8			2.8		
Overtime	0.3			2.8		
Guarantee	2.6			1.7		
Total Paid Hours	67.7			69.0		
Pay/Plat Ratio	1.2025			1.2661		

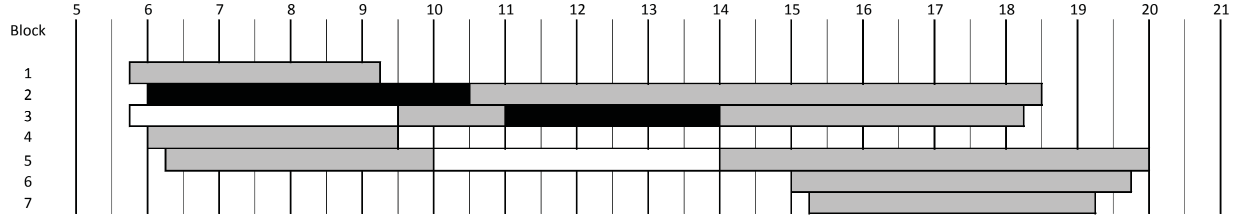
The major structural change is that two full-time straight runs are replaced by two part-time runs. The total runs remain unchanged, and the total worked and paid hours are only marginally different. A careful review of the runs themselves, including operational impacts and operator preference, would be needed before a realistic answer could be provided. However, at first glance the change does not appear to be significant.

Note that this example allowed meal breaks to be unpaid. This is not necessarily the case at all agencies, where labor rules may require breaks to be paid. Meal breaks are likely to be costly if paid and/or if required to be taken at the garage. Later in this chapter we note the potential impacts of such restrictions and discuss the operational desirability of these solutions.

Approach 2: Operator Drop-backs

Cutting runs for meal breaks using operator **drop-backs** (also known as fall-backs) is similar to the process described above. But in this case the operators are not required to return to the depot for their meals, and so have the meal break at the terminal.

The procedure is relatively straightforward. Looking at the headway sheet, we can see that Block 2 passes the relief location (Point A) at 10:39. We cut the piece here. Then Block 3 passes through at 11:09. We cut the start of the next piece here. That gives a run with a drop-back (or break) from 10:39 through to 11:09 at Point A—shown as the black "run" in the diagram below. The same process can then be applied to Blocks 3 and 5, providing a meal break between 9:39 and 10:09 (the white "run" below). This process then cascades as a series of drop-backs are generated, each allowing the operator a 30-minute break at Point A. At the end of the process we would (hopefully) have a more efficient runcut, as we have avoided travel to and from the depot associated with our previous runcut.

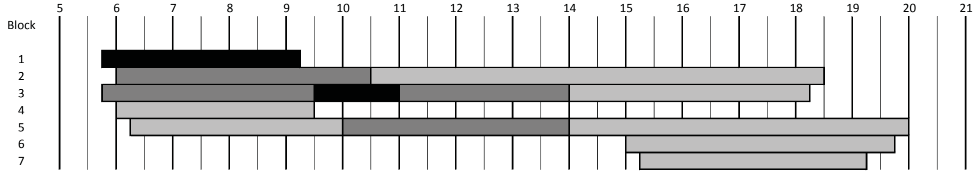


However Block 1 presents us with a more complex situation. It ends at Point A at 9:09 and then pulls back in to the depot. If we create a "run" shown in black on the diagram below we are left with a pull-in to cover, since the drop-back starts at 9:09 at Point A, and the operator gets off the bus. We could have a split run with a drop-back on Block 4 at Point A between 8:39 and

drop-back

A technique where the operator or train crew gets off an arriving vehicle at a terminal, takes layover, and assumes operation of the next vehicle to arrive. Most common on frequent rail lines where close headways do not allow sufficient layover time for the train crew, this technique is also used for special events to maximize the number of trains in service. If service is very frequent, the train crew may not board the next train but instead the train after that; this is called a "double drop-back." Some agencies use the term "fall-back" instead.

9:09, with the run then covering the pull-in. However this may cascade and result in an infeasible solution.



At this stage we could go back to the approach used in the previous section and possibly rehook the blocks, much as we did then. In undertaking this approach we could effectively rehook the blocks and create a set of long layovers, each 30 minutes, at point A. But we would not do this for all links at Point A, just for those that require a meal break in our runs. The operator would then have a 30-minute meal break in his or her vehicle. But would the break be 30 minutes? In fact it would not—the operator would get the 30-minute break plus the layover before the next trip of 21 minutes, resulting in a 51-minute break.

Meal Break Runcut Issues

The runcuts above indicate that meal breaks can be achieved for our revised Line 97 runcut with only a minor change in paid hours. Again, this was based on relatively liberal rules around the meal break requirements.

As initially noted, many transit agencies assume that meal breaks will automatically result in significant cost impacts. The likelihood of meal breaks resulting in increased or decreased run cut efficiencies depends on a variety of rules and approaches. These include the following.

- Meal breaks are more likely to result in reduced efficiencies if the breaks are paid. In the example above paid breaks would have added three hours, or 4%, to the overall runcut cost. A 4% cost impact would be at the lower end of expectations, based upon general experience.
- Multipiece runs (i.e., those with meal breaks) allow improved control over the length of one runs. Take the example of a one-piece run from an earlier solution. The vehicle only passed the relief location once every 90 minutes. Therefore if it passed at around 7:30 into the block, we are left with either an expensive (due to guarantee) short run, or increased overtime (taking the 9:00 relief option). Multipiece runs, however, often allow runs to be created at a preferred length, according to the transit system’s preferences. This advantage is often overlooked.

- The efficiency impact of meal breaks can be reduced if meals are not required to be taken at the garage. In the example above, the cost would have reduced by almost two hours and the "with meal break" runcut would have been less expensive than the "no meal break" runcut had the operators not been required to return to the garage for meal breaks.
- An additional benefit of meal breaks is they obviate the need for consistently long layovers in blocks (which act as de facto meal breaks, but potentially occur several times a day and are paid). In one-piece runs with no prescribed meal break, there is a natural expectation of layover to allow operator rest periods, often in the form of longer layovers. The potential impacts are both additional vehicles (through increased cycle times) and longer total nonproductive times, as the longer layovers tend to result in several rest periods per day. The implementation of meal breaks can therefore allow an opportunity to reduce those longer layovers that exist as a surrogate for meals and reduce overall operating costs.
- Pull reliefs can be used in either type of runcutting approach to meal breaks. However, this needs to be carefully handled in order to avoid increasing peak vehicle requirements or excessive mileage.

The table below summarizes some specific existing conditions where implementation of meal breaks and rest breaks can impact on runcutting efficiencies.

Rule/Parameter	Low Cost Impact	High Cost Impact
Meal Break Paid/Unpaid	Unpaid meal breaks. If unpaid, the meal breaks do not add unproductive time.	Paid meal breaks. Adds (typically) 30-plus minutes of unproductive time, reducing the productive time in a work day. Likely to result in increased paid hours and increased operator requirements.
Meal Break Location	Away from Garage (can be either at the terminal or some other nearby location). Allows the meal breaks to occur without significant increase in travel requirements.	At the garage or limited locations. Causes increased travel times around the meal breaks.
Relief Types	Street reliefs allow more flexibility in cutting runs with meal breaks, without necessarily increasing operational costs.	Pull or car reliefs can result in higher mileage costs where meal breaks are required, depending on meal break location requirements.

Rule/Parameter	Low Cost Impact	High Cost Impact
Overtime, Guarantee, and Run Length	Where runs must be cut close to a predetermined length (e.g., eight hours), the ability to match long and shorter pieces together to get close to the preferred run length can actually reduce overtime and/or guarantee costs.	Where run length is not an issue, e.g., where overtime is paid weekly and not daily, the matching of shorter/longer pieces will have less benefit.
Relief Frequency	Where reliefs occur infrequently (e.g., long routes with one relief location), one-piece straights tend to have higher guarantee and/or layover, as relief opportunities around eight hours are limited. Again the ability to match shorter/longer pieces presents an opportunity to reduce costs where meal breaks are utilized.	Where relief locations are frequent and existing one-piece runs can be cut at around eight hours, the matching of shorter/longer pieces will have less benefit.
Layover Requirements	Where existing layovers act as pseudo-meal breaks (where no official meal break exists). In effect this means a meal break replaces an unofficial paid break, and has the potential for a net reduction in costs.	Where existing layovers do not provide built-in breaks and meal breaks need to be created in addition to existing layovers.
Run Cut Approach	Pieces are recut into multipiece runs with a meal break in between. The example above showed how meals can be created without any significant costing impact using this approach	The approach using operator fall-backs could reduce flexibility in cutting and matching pieces to create runs, where meal breaks have been applied.

Relief Types Revisited

When discussing scheduling inputs we covered the basics of relief types. However, these were presented as the basic types and only a limited discussion was provided. At this point, after undertaking several runcut solutions, with different types of reliefs involved, further exploration is warranted.

We may want to change our approach to reliefs to improve the efficiency of the runcut, make the solution more operationally robust, or both. These are key goals that the scheduler should be striving to achieve for each and every runcut.

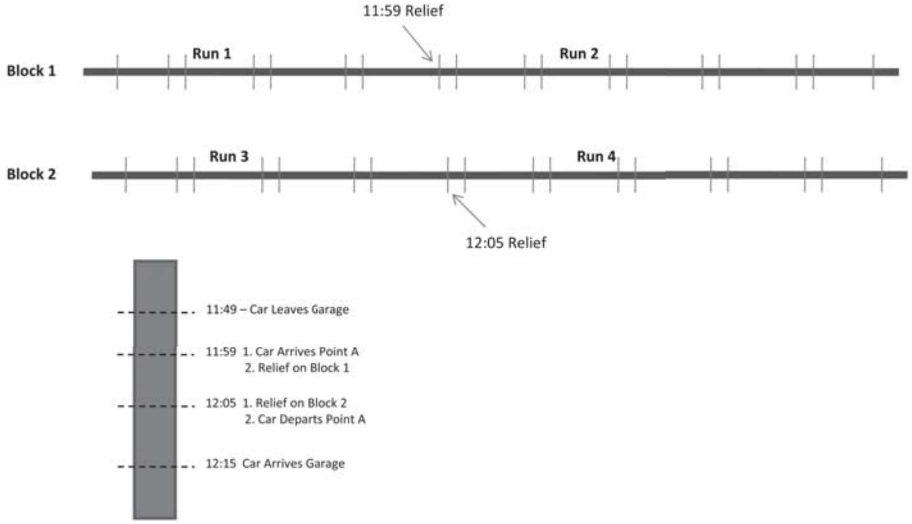
Car Pooling

There are cases when a car can be used to ferry more than one operator between the garage and a relief location, or even between two relief locations. This is known as car pooling.

Take an example where we have a relief at Point A at 11:59 (relief for Runs 1 and 2) and 12:05 (relief for Runs 3 and 4). With a travel time of ten minutes this cannot be achieved by the same car, as it will get back to the garage at 12:09 from the first relief, but needs to have left at 11:55 to make the 12:05 relief. A second car would be required to perform this function.

However it would be possible for one car to be used to accommodate both reliefs. If the car leaves the garage at 11:49 (to make the 11:59 relief) it could carry the operators starting at both 11:59 and 12:05). And on the return journey it would leave at 12:05 and arrive back at the garage at 12:15. The only cost implication is that Run 3 now leaves the garage 6 minutes earlier (at 11:49 instead of 11:55 to make the 12:05 relief) and Run 2 arrives back at the garage 6 minutes later (12:15 instead of 12:09 after making the 11:59 relief). In both cases the affected operators are delayed by 4 minutes at the relief location Point A.

The diagram below depicts this simple example of car pooling.



The total runcut cost of this change is eight minutes of paid time (potentially 12 minutes if there is overtime or spread premium involved). However this is offset against the cost of purchasing, managing, and maintaining an additional car. The calculation would clearly indicate a significant cost saving.

The scheduling of car pooling can become quite complex as multiple relief locations, cars, and operators are considered. For example, one car could drop an operator at one location, collect the driver relieved, drop a second operator at a second relief location, and return to the garage with the two returning operators. The approach to car pooling will be based upon how much additional time can be added to the runcut to enable a reduction in car requirements and mileage. Most computerized systems have a means for displaying these car blocks and indicating which operators are car pooling.

As with vehicle trips and blocks, car trips and blocks need to be carefully managed and well documented. For a relief to occur, the relief driver needs to be able to get to the right place at the right time.

The car trips in the example above are shown in the following diagram.

From Garage				**To Garage**			
Driven By (Run #)	Passenger (Run #)	Leave Garage	Arrive Relief	Driven By (Run #)	Passenger (Run #)	Leave Relief	Arrive Garage
1	3	11:49	11:59	2	4	12:05	12:15

Travelling on the Service

Many agencies allow operators to travel as a passenger on an in-service vehicle to and from relief locations. The benefit of this approach is to avoid the need for cars (and their accompanying costs), or pull or deadhead mileage. This approach can only be used where a route actually passes close to the depot and the relief location.

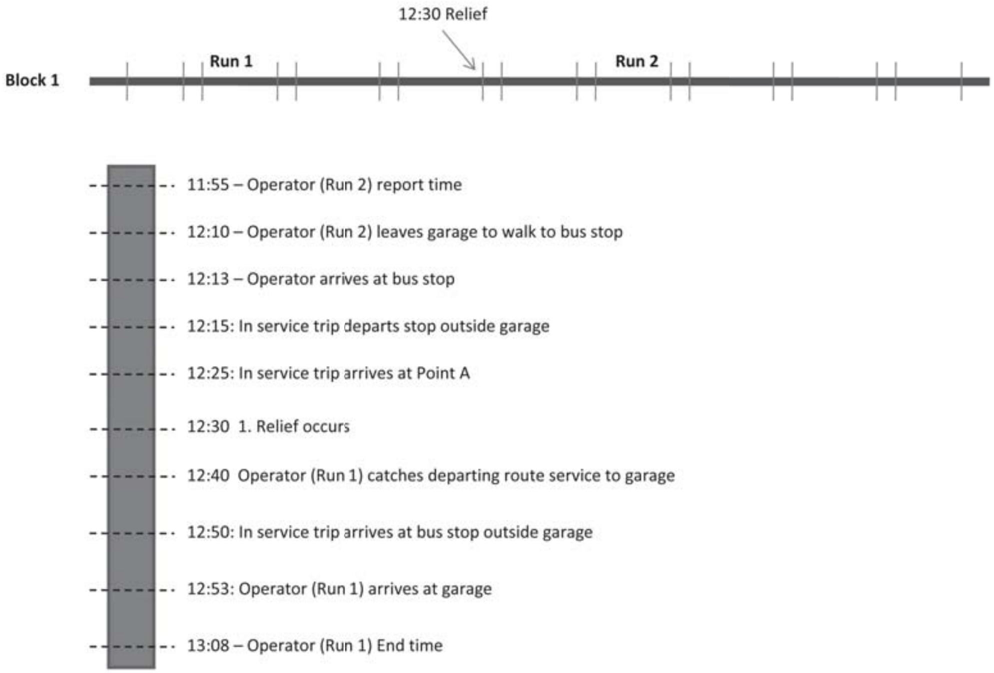
Many agencies tend to use average travel times for such reliefs. This approach is flawed and risks several poor outcomes. Typically the costs will be higher as agencies have to make a conservative estimate of the travel time required to avoid missed connections or reliefs. It also risks missed reliefs if the allowance is not high enough at times when running times are highest.

A more realistic approach is to use the actual scheduled times, perhaps with a late running buffer, to generate the travel requirements. This ensures the appropriate time is used for each individual relief, inclusive of running time variations during the day. The calculation is quite simple:

1. Work back from the relief time and location. If a relief occurs at 12:30 at Point A, look at the schedule for the arrival at that location nearest to 12:30, but with enough time to cover late running. If an in-service bus arrives at 12:25 or earlier, that would be ideal.
2. Working back from the 12:25 arrival look at the schedule to ascertain when the bus passes the garage. Add any walk time needed to get to the bus stop from the garage, and that is the time for the operator to leave the garage.

The diagram below depicts the calculation of travels using service trips. The assumptions are:

- Report/sign off times: 15 minutes
- Walking time to stop outside garage: 3 minutes
- Scheduled trip run time of 10 minutes to Point A (relief location)
- Service frequency of 10 minutes on the route used for travel
- 5 minutes minimum buffer required either side of relief



11:55 – Operator (Run 2) report time

12:10 – Operator (Run 2) leaves garage to walk to bus stop

12:13 – Operator arrives at bus stop

12:15: In service trip departs stop outside garage

12:25: In service trip arrives at Point A

12:30 1. Relief occurs

12:40 Operator (Run 1) catches departing route service to garage

12:50: In service trip arrives at bus stop outside garage

12:53: Operator (Run 1) arrives at garage

13:08 – Operator (Run 1) End time

Note that Run 1 could have potentially caught a 12:30 trip back to the garage. However a zero-minute connection was ignored as we required a five-minute buffer between the relief time and travel trip.

Some computerized scheduling systems have features that enable a matrix of "travel in service" trips, inclusive of using other modes or even taking two routes to get to the relief location. With these features, if you are lucky enough to have a system with this feature, all you need to do is provide the computer with the "rule" on how tight a connection you will allow and identify any time of day restrictions.

Reliefs During Layovers

Thus far, all of the runcut examples have used the arrival time at a trip terminal as the relief time. This is the normal approach used in most cases because it allows a buffer (the layover) for late arrival at the relief location by the new operator. It also allows the relieving operator the time to get onto the vehicle, adjust the seat and mirrors, and key in any necessary information to the farebox.

However there are cases when reliefs are not possible or preferred at the time of arrival at the terminal. For example one piece may extend beyond the maximum allowed before a meal, or run length. There are numerous reasons that a relief at a specific time may not work or be preferred. Some of these are noted below.

In our Line 97 example we have 21 minutes of layover time at Point A, meaning there are a number of alternate options available. In the case of our drop-backs problem, cutting Block 3 during the layover (9:09 to 9:30) may have allowed pieces from Blocks 1 and 3 to be matches to form a straight run, whereas the relief time of 9:09 did not.

There may be cases where paid time can be reduced by reliefs during layovers. If a block is cut into two straight runs, one 7:45 and the other 8:15, it may be possible to move the relief 15 minutes (assuming at least a 15-minute layover) and save 22 minutes of paid time.

The use of car pooling for reliefs may need some relief times to be shifted through layovers to allow a car to carry multiple operators.

In these cases the relief can simply be made at any minute during the layover time. However there would be a loss of simplicity in the runcut, as the rule of thumb approach that "reliefs occur upon vehicle arrival at a terminal" has been violated. Finally, this option is only possible where a layover exists. At a midpoint relief location where there is no dwell or layover time, the time at that point must be the relief time.

Pull Reliefs, Blocks, and Runs

Pull reliefs present another option for meeting the aims of the scheduling process. Going again back to our runcut for Line 97 we can take an example Block and apply a pull relief. This means that the 12:09 relief becomes a pull relief and the runs look like the following:

Original - Sreet (Car) Relief

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Travel Hours	Total Hours
				Time	Place	Type	Time	Place	Type					
1	Str	2	5:46	6:01	Garage	Pull	12:09	A	Street	12:34	6:08	0:30	0:10	6:48
2	Str	2	11:44	12:09	A	Street	18:38	Garage	Pull	18:53	6:29	0:30	0:10	7:09

With Pull Relief

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Travel Hours	Total Hours
				Time	Place	Type	Time	Place	Type					
1	Str	2	5:46	6:01	Garage	Pull	12:19	Garage	Pull	12:34	6:18	0:30	0:10	6:48
2	Str	2	12:05	12:20	Garage	Pull	18:38	Garage	Pull	18:53	6:18	0:30	0:10	6:48

As the example shows, by using a pull relief we create a later start time for Run 2. How is this possible? Simply by the fact that for pull reliefs the layover does not need to be covered. The first bus finishes the trip at 12:09 and pulls straight back to the garage, and the second bus pulls out to arrive in time for the 12:30 departure. If this same approach is applied for all three reliefs of the straight runs the net cost outcome can be summarized as follows:

Costs:

- Additional 21 vehicle miles (3.5 miles per trip x 3 round trips)

Savings:

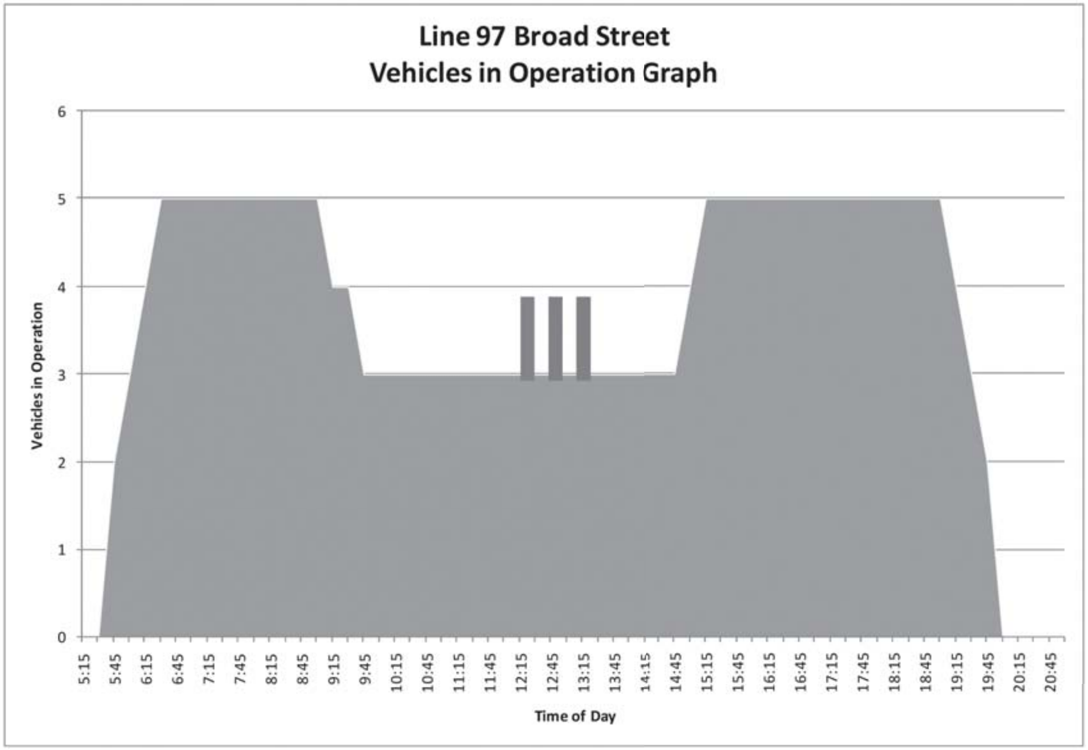
- 1:03 worked time (may not translate to paid time if the run is below 8 hours)
- 21 car miles
- 1 car

In this case it would appear that the savings clearly outweigh the costs. There is however an impact of the vehicles being used at any one time, which now looks like the following.

pull reliefs

Reliefs made by pulling out one vehicle and pulling in another vehicle.

Tip Limit the use of pull reliefs to midday when a pull relief will not increase vehicle requirements beyond the peak requirement for the route. Like operator hours, the maximum vehicle count is important and needs to be minimized.



We see a spike in the vehicles required from three to four at times when the pull reliefs occur. This assumes (reasonably) that the 12:19 arriving bus cannot be the same bus as the departing 12:20 bus.

A strong benefit of this approach is that on-time performance of some trips is no longer dependent on the trips that preceded it, but rather is dependent only on the pull-out trip arriving on time. Since pull-out trips are easier to manage than time delays associated with in-service trips, the outcome should be improved service reliability, something all runcut solutions must look to achieve.

There are of course circumstances where use of pull reliefs does not provide savings but instead incurs increased paid hours and increased mileage—relief locations farther from the garage or with minimal scheduled layover for example. And a pull relief during the peak, with an accompanying additional vehicle, is not acceptable scheduling practice.

There may be other reasons, such as maintenance issues, to avoid pull reliefs. In the example above there are now fewer vehicles available between 10 AM and 3 PM, a preferred maintenance window. Schedulers need to consult regularly with operations and maintenance staffs, especially if they are changing historic practice with reliefs, conditions for operators, or vehicle requirements.

Relief Simplicity

There is at times a tradeoff between simplicity and minimizing costs. Often the solution that would result in the lowest overall costs is too complex to run reliably in the field. Use of reliefs is a classic example of an opportunity to achieve the right balance.

Mathematically the more relief points there are, the better the chance of finding an optimized runcut solution. In fact the great constraint of transit runcutting over creating shifts with variable start/finish times is the limitation of when operators can get on and off the vehicle, to start or end their run. So from a mathematical viewpoint it would be ideal to have a potential relief at every bus stop.

However excessive use of relief locations and types can complicate operations to the point of making the service less reliable. Car pooling is an example where there are clear efficiencies to be gained. However, as soon as the schedule relies on a second operator’s trip arriving at the relief location to allow the first operator to travel to the garage on time, the likelihood of service problems increases.

The same approach to defining relief locations applies. While it is possible to have relief locations at numerous timepoints throughout a route, operational simplicity suggests limiting this number. If operators know that Point A is the terminal and relief location for Line 97, there is certainty. If occasionally Point B is used for reliefs, we have instantly introduced the chance of operator error (e.g., missing the relief at Point B and continuing to Point A, leaving the relieving operator stranded).

The same concept applies to relief types—if relief to Point A is a car travel some times, travel in service at other times, and pull yet others, the chance for errors, resulting in service reliability impacts, increases.

This is not to say that everything needs to be kept as simple as possible in all instances. It is up to the scheduler to work with operations staff and develop an understanding of the cost impacts of various approaches. Then the agency itself can consider the tradeoff as a policy decision, based upon facts.

Exception/Events Scheduling

Scheduling for ever-changing circumstances places a significant work burden on the scheduler. It also has a range of efficiency and complexity impacts.

There are primarily two types of "events" that affect schedules in a way that can be anticipated and written into the runcut. One is the special event such as a sports event or concert. These may require additional service on an occasional or semi-regular basis. The second type relates to changes to regular trips—either by day of week or perhaps time of year (school time/non-school time, for example).

In both cases, there are well-utilized scheduling techniques that can be employed to minimize operational complexity while maintaining scheduling efficiencies.

Creating Base Solutions to Fit Known Events

In order to accommodate known events, depending on the frequency of the event, it may be wise to create a runcut solution (and blocking solution for that matter) that will allow the revised or extra services to be readily incorporated.

For instance this may mean cutting pieces in the regular runcut that can be extended for later service. If we take a "typical" 12-hour block, to be cut into four-hour split piece and an eight-hour straight piece, we have a choice when to cut it—as a morning straight with a PM split (or part-time) piece, or as a morning split piece with a PM straight. If an agency has a semi-regular night event, it may be wise to schedule as an AM straight with a PM piece left as a part-time run. This piece can then be readily extended to cover the event.

The approach to such schedules must be tailored to suit the specific requirements of a transit system. Forward planning in conjunction with operations staff can allow additional services to be accommodated effectively and efficiently.

Dealing with Day Exceptions

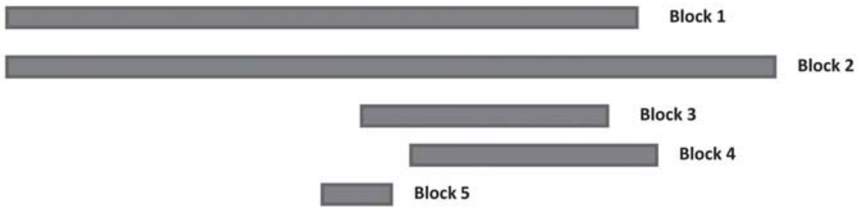
Day exceptions relate typically to school services, or to services that operate differently on different days. Examples include:

- School holiday versus school day schedules, where extra or altered services may operate;
- School day exceptions for early or later bell times; or
- Additional services running later on a Friday or Saturday night.

A good approach is to maintain, as much as is reasonably possible, consistent schedules, blocks, and runs. What do we mean by this? Take a block with extra (later) Friday night trips, as below.

The regular block is 15 hours long whereas the Friday block is 17 hours long. When cutting the block into two straights for Monday–Thursday the scheduler should consider how the run will finish on Fridays. This way the blocks and run can be kept the same for all days with a later finish on Friday (but the same block number and run number).

School exceptions provide a more difficult task. One solution is to keep the school blocks as separate as possible. This can however affect efficiency, both in terms of extra mileage and even potentially additional peak vehicles. Where the school blocks are kept separate, the PM Peak can look something like the following.



Here we have a very short one-trip school block (Block 5) that operates as a stand-alone vehicle. We are left with two choices for blocking and runcutting this trip. At the runcutting stage we see that it has been blocked stand alone. We also see an obvious opportunity to hook the end of Block 5 with the start of Block 4 to create a more efficient run.

But should we make this change? The answer depends on the amount of exceptions that apply to the school trip. If the changes only tend to be earlier bell times then we get to keep a consistent run across all exceptions by hooking the two pieces into a single block and part (or all) of a run. If this is the second part of a split run with a sufficiently long AM piece, this run would operate during both school and vacation periods, as well as during exception days. Again we have achieved a desirable operational outcome—simple and efficient.

The use of computerized systems to manage exceptions and events enables the scheduler to more readily create integrated solutions across regular and exception schedules.

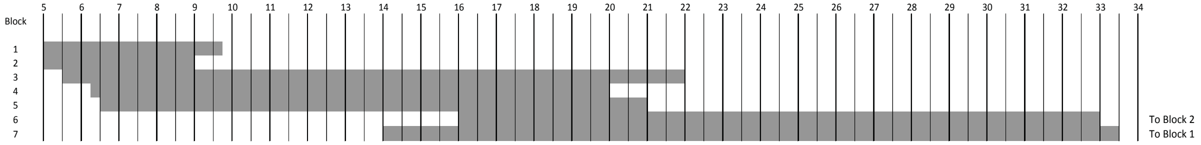
Owl Scheduling

Scheduling for "owl" or overnight services presents the scheduler with an unusual question—when does one day end and the next one begin? There are two basic approaches to scheduling for owl services, and these are discussed below.

Continued Blocks and Runs

The most efficient way to schedule owl blocks and runs is for the vehicle to continue on during the AM Peak and finish after the peak. Under this approach it is best to have the all-night blocks being the pre-PM peak pull-outs to avoid excessive block and run length. However this means that in effect the block covers both "today" and "tomorrow," and the scheduler must understand this to be able to create runs.

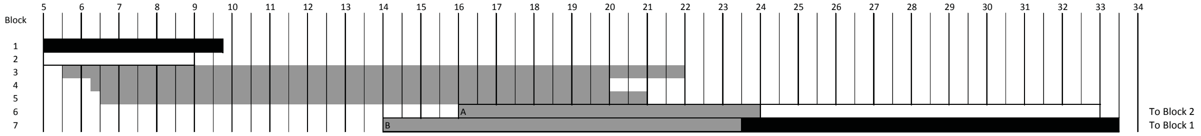
The diagram below depicts this approach to scheduling all-night services.



Note that Block 1 is effectively the end of Block 7, and Block 2 is effectively the end of Block 6. The blocks operate from around 3 PM until around 9 AM the following morning.

How can we cut these runs, present the information, and avoid mistakes? In the example provided we have two blocks of 17 and 19 hours duration. Assuming we have one-piece straights creating the runs is simply a case of cutting them somewhere in the middle, to create two straight runs per block. In the case of Block 7 this would mean a cut at around 23:00. This leaves us with a run commencing around 11 PM and working through until 9 AM the following day.

Conceptually this is not difficult to handle. But in practice this effectively means that Blocks 1 and 2 are already covered and in effect don't exist, or are just "dummy" blocks and pieces. This is shown below:



Cut Blocks and Runs

An alternative is to cut the blocks by use of pull reliefs. The same concept as the above example can be applied, but the buses instead pull out and in at around midnight, giving 2 blocks from 2 or 3 PM until midnight, and another two from midnight until after the AM peak.

The blocks could be cut at a number of different times—for example after the PM peak, and before the AM peak. This would leave shorter peak blocks, with longer blocks from around 7 or 8 PM through until 5 AM—in effect a single-piece owl run with a stand alone vehicle block.

Impacts of Different Service Days

One of the difficulties lies in transitioning between different service types. In the example above, on a Friday night, Block 6 cannot connect to Block 1, since Block 1 does not necessarily exist, certainly in the same form as weekdays, on Saturday. And the same problem occurs transitioning from Saturday to Sunday, and Sunday to weekdays.

This means that the scheduling becomes quite complex if the "continuous blocks" approach is applied, since it means having a separate Friday runcut with a separate "dummy" type run for the Saturday AM continuation. The alternative approach, cutting the blocks through pull reliefs into independent runs, is more operationally expedient and keeps the scheduling more streamlined. However there is a cost associated with the additional mileage resulting from the extra pull trips.

Under either approach, issues as to when one day starts and another ends, and when the owl runs actually begins, need to be resolved.

Runcutting Issues

This section describes several policy issues related to scheduling of labor resources. The discussion is by no means exhaustive, either in the number of issues that are discussed, or in the discussion of each issue. The aim here is to make schedulers and others within transit systems aware of some of the more important issues around runcutting.

The differences in work rules, policies, and approaches across agencies make it impossible to provide solutions that will work at every property. We hope that readers use the discussion to better understand the issues and review their thinking in light of specific requirements at their particular system.

A. Overtime Optimization

The normal work week is thought of as eight hours a day, five days per week, totaling 40 hours. While there are variations (4/10 is a common example), the weekly total for the typical full-time

American hourly worker is 40 hours. Yet as everyone involved with scheduling and operating transit service soon realizes, transit operators rarely fall into what office workers take for granted as a "standard" work week. If a run does pay exactly 40 hours it is almost certainly because make-up time has been added to a shorter run to bring the run up to a required 40 hours.

Why is this? Simply stated, it is the rare route where one-way running time, plus recovery/layover is exactly 60 minutes. And then, of course, there are pull-out and pull-in time to consider. So schedulers are constantly balancing between paying extra "make-up time" to bring full-time runs up to a required 40 hours and paying overtime for work in excess of 40 hours per week. Runcutting is in essence a balancing act, finding the optimal point where the number of overtime hours is optimized to produce the lowest overall cost to the property, within the restrictions of your labor agreement.

The optimal amount of overtime is not always the lowest amount. Take for example a schedule with 72 hours of work to be divided into daily runs. In the simplest example, this work could be divided into nine 8-hour runs or eight 9-hour runs. Actually, in the simple convention of computing overtime on a daily basis (this topic—daily versus weekly overtime—is discussed further in Chapter 6: Rostering) eight 9-hour runs will pay 76 hours (including 4 hours overtime pay, assuming a time-and-a-half rate for overtime), or 20 hours more per week than nine 8-hour runs. However, we should not assume that the runs with the least overtime actually cost less. It may seem counterintuitive but paying out some overtime can actually SAVE money.

The reason is simple; it may be cheaper in total payroll costs, overall. When there were 72 hours paid daily, rather than 76, there were nine people payrolled. With 76 daily pay hours, there were eight people payrolled, or one less. That is one less set of benefits: medical benefits, pension benefits, insurance, etc. It also is, from a risk management standpoint, one less risk of/exposure to disability, long-term absence, etc. Further, depending on the agency's wage rates and expenditures for unscheduled overtime (when an operator works a second run in the same day, etc.), Social Security (FICA) costs may be avoided. Taken together, these types of benefits are known as "welfare" benefits, as they are focused on the health and welfare of the operator.

There are also "leave" benefits. These are the ones that influence and impact an operator's daily attendance such as vacation, holidays, personal days, etc. Also included in this group are the days that cause an operator's absence from the seat of the bus but are not "away from the office," so to speak. This includes those days when the operator is at work but not driving in revenue service such as training, filling in for a road supervisor, court appearances (due to an accident witnessed, for instance), etc.

If the combined value of these benefits is actuarially 50.1% or greater than the average system base wage rate, then paying overtime will almost always be less expensive for the agency than adding additional payrolled bodies. Indeed, theoretically under such circumstances there should be no limit on overtime. But other contract limitations/collaterals (maximum spread)—and the humaneness and safety implications—dictate not going overboard.

How does an agency go about determining its optimum scheduled overtime? It is indeed an actuarial effort because the key factor, the linchpin so to speak, in making the determination is its typical operator (employee) availability, i.e., what remains after the leave benefits are used. In a normal work year, an employee is paid for 260 days (five day work-week multiplied by 52 weeks per year). If the average employee took 10 days off, while paid for 260, s/he would have 250 days of person-day-availability, or PDA. With its mean PDA of 250 (96.2%), the agency knows that based on typical availability, for every 25 operators payrolled, it needs another one. That's because for every day the operator doesn't work his/her run, another operator needs to back fill to cover the work.

Only 10 days off per year—or not working in revenue service—is highly unrealistic. In addition to vacation, there are holidays, personal days, training, sick leave, long-term disability leave, an operator filling in for a vacationing road supervisor, and other reasons for absences. When computed on a systemwide basis—particularly with an older work force—230 PDA is considered quite good (88.5%); 240 (92.3%) extraordinary. In the case of the 230 PDA, for every 25 operators payrolled, another 3.3 are required. There are numerous systems—particularly larger ones with an older complement of operators—where 200 PDA is not uncommon. That 77% availability translates into 7.5 additional operators for every 25 payrolled to fill runs. (This is, of course, also one of the fundamental building blocks in determining extraboard size.)

Thus, in trying to determine the optimum amount of overtime, in addition to the welfare benefits listed above (medical insurance, FICA, etc.), the cost of leave benefits to the agency—vacation, sick, personal days, average number of days in training, etc.—on an individualized basis must be ascertained.

Adding operators to the payroll adds both the cost of welfare benefits and the cost of leave benefits to the payroll. In effect, it is hard to add only one operator since you also have to add enough bodies, either through extraboard or other means to cover for operator leaves.

To determine the value of leave benefits attributable to an individual, an analysis of the agency's overall operating budget/costs is required. Simply stated, this analysis takes all leave costs and apportions those costs to each operator budget position. This is a daunting effort involving many different departments (human resources, labor relations, payroll, treasury and finance in addition to transportation). It is certainly not something that is done with every sign-up but should be done occasionally to revisit the policy on overtime and to provide guidance to the scheduler when deciding how much overtime to put into runs.

It is after that cost determination is made—with the realization that each operator brings to the payroll not just salary costs but the mathematic probability of exposure to collateral long-term costs such as disability payments in addition to those of his/her “benefits package”—that the size of the optimum run that includes built-in, scheduled overtime can be established.

B. Part-time Operators

The previous section considered some of the key factors in optimizing overtime costs. This initial discussion however failed to take into account alternatives for the makeup of the runcut. Use of part-time operators can affect the types of runs used, the cost of the runcuts, the use of full-time operators, and a range of subtle outcomes.

Again this document will not attempt to provide a prescriptive assessment of the benefits of part-time operators, but instead discuss some of the more important scheduling-related concepts

TCRP Report 68 indicated three key cost saving influences of part-time operators:

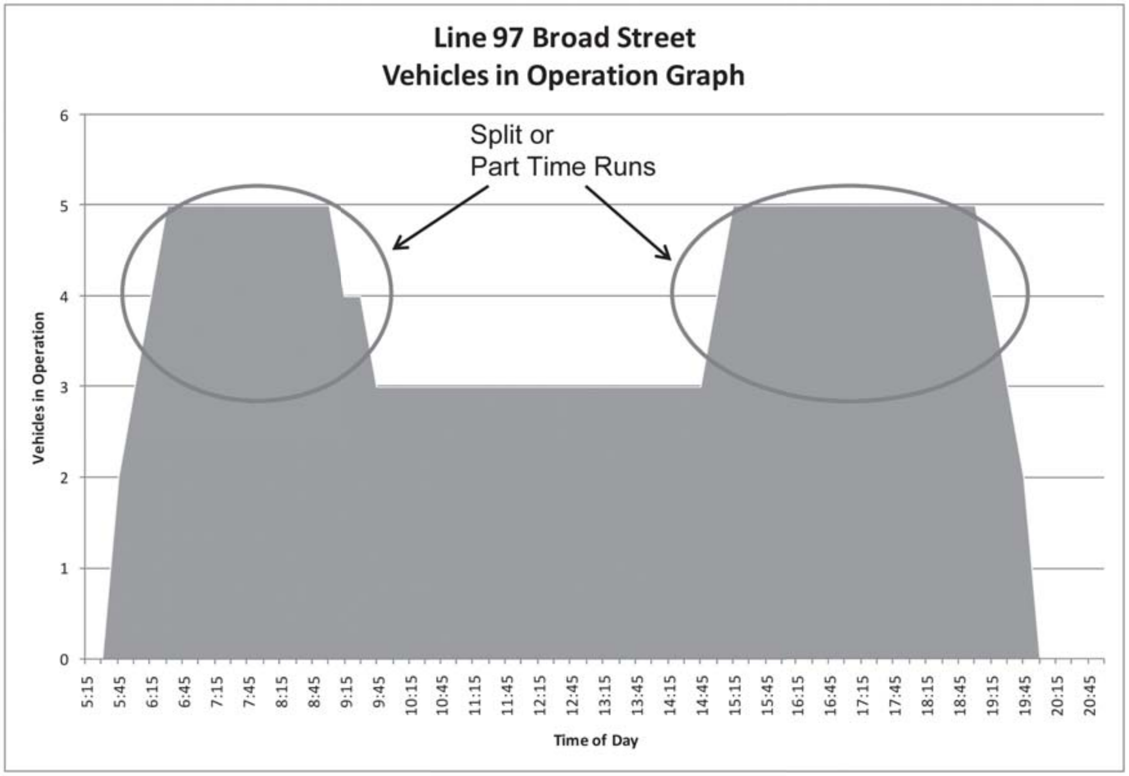
- They permit transit agencies to reduce the amount of premium and guaranteed pay entailed by a service schedule staffed entirely by full-time operators;
- Part-time operator wages are generally lower; and
- Part-time operators generally have lower fringe benefits.

Which Situations Best Fit Part-time Runs?

Traditional scheduling approaches suggest that part-time runs are best suited to dealing with highly peaked situations, or where rules are complex and the number of constraints is high. The traditional industry model for part-time operators is to create runs of up to six hours in length, allowing up to a five-day 30-hour workweek.

The first situation allows part-time runs to be substituted for split runs, thereby resulting in reduced spread premiums and potentially avoiding guarantee or overtime costs. The second case allows smaller pieces to be created that allow the overall runcut solution to be optimized.

If we go back and look at our simple Line 97 example we see potential for some blocks to form either split or part-time runs. In this case there are two blocks in either peak that were used as a basis to form split runs in an initial runcut.



If we simply take those four pieces of work assigned to split runs and convert them to part-time runs the cost impacts can be easily reviewed, and are provided below.

	Split	Part Time
Total Runs	2	4
Platform Hours	15:01	15:01
Travel Hours	0:30	0:30
Spread Premium	2:46	
Overtime	0:35	
Guarantee	0:00	
Total Paid Hours	18:52	15:31

In this example the savings of using four part-time runs to replace the two split runs is over three hours and equates to almost 18%. If the hourly rate for the part-time operator is lower than for full time the savings become even more significant. It may also be possible in other cases for part-time operators to work two small peak pieces (assuming total work time is within labor rule limits), thereby replacing some split runs on a one-to-one basis. Appreciable gains in efficiency can be achieved by this strategy.

This is a basic example, and the conditions for splits and spreads made the split runs relatively inefficient to begin with. However, it illustrates the potential savings that creation of part-time runs can provide. Part-time runs may also be useful where there is an imbalance between the peaks and the peak blocks cannot all be assigned to split runs. Chapter 6: Rostering notes another potential benefit of the use of part-time operators: to fill open run imbalances on certain days of the week.

Use of computerized scheduling packages can allow more sophisticated modeling of the impacts of varying levels of part-time runs, where total paid hours can be compared and multiplied by actual wage rates.

More Complex Runcutting

The example presented described a basic situation with relatively simple rules and few constraints or limitations. There are many more situations where part-time runs can be effectively used to produce an efficient runcut.

The complexity of work rules around all run types can result in pieces of work that are difficult to assign to full-time runs. For example, in the meal breaks section we created a runcut that required two smaller pieces of work, which were then assigned as part-time runs.

A set of more highly constrained work rules is more likely to result in a need for shorter run types ideally suited to part-time operators. As the complexity of the rules and number of constraints increase, it becomes more difficult to cover all of the blocks with full-time runs.

Typically there will be a limitation on the number of part-time runs that can be created within a runcut or assigned in a roster. In many cases the “optimal” number of part-time runs, from a runcut perspective, will be close to or above this limitation.

Operational and External Impacts

The above discussion indicates the well-known potential efficiency benefits in application of part-time runs and operators. However there are a number of other issues relating to part-time operator deployment that can affect the overall benefits.

The relative competence, training requirements, and retention rates of part-time operators all affect the overall benefits of their use. These factors can translate into measurable cost impacts such as higher accident rates or increased unscheduled overtime (through either increased absenteeism or unfilled operator positions). The specific impacts of such factors tend to be local in nature, and our research indicated different viewpoints as to the benefits or costs relating to part-time operators across different transit agencies.

Ideally historical data at an agency can be obtained, and any related factors can have costs or values applied to allow a reasonable estimation of the total impacts (i.e., measure the runcut or roster savings against any operational or external cost impacts).

C. 10-Hour Runs

Ten-hour runs and rostering of four 10-hour days for a driver work week offers another tool to schedulers. As with the discussion of balancing overtime and part-time operators, introducing 10-hour runs can be considered as purely a runcut issue, or as a runcut and rostering issue.

Returning to some of the examples presented above, creating longer runs at the runcut level is likely to result in reduced travel, report, and guarantee. Taking another simple example we will look at 100 hours of platform time and assume the runs can be cut as either all eight-hour or all 10-hour. We assume that there are 40 minutes of report and travel time for each run, and that we are looking for an average of 8:00 and 10:00, respectively.

	8-Hour	10-Hour
Total Runs	13.3	10.5
Platform Hours	100.0	100.0
Report Hours	6.7	5.3
Travel Hours	2.2	1.8
Total Paid Hours	122.2	117.5
		-4.7
		-3.8%

The idea here is to demonstrate that, as fewer runs are created, the total cost of travel time and report time is likely to decrease because these cost factors are related to the number of runs.

Rules Affecting 10-Hour Runs

There are of course many different implementations and rules governing the use of 10-hour runs, differing by agency. However some general types of rules exist and may specify:

- The minimum and/or maximum number of 10-hour runs allowed, usually expressed as a percentage of total runs
- Overtime and guarantee will tend to apply at the 10-hour mark and not the usual 8-hour mark
- Spread penalties will apply, but probably only to split runs
- Other rules will be applied to 10-hour runs as they are to eight-hour runs

Workforce Factors

While the example above would suggest that 10-hour runs are a tool for saving money, the reality is not that clear. The assumption with 10-hour runs is that they are tied to four-day workweeks. If a 10-hour solution requires more operators to be hired, it may actually be a higher cost solution since every operator comes at a fixed cost for benefits. At this stage we need to take a step back and consider the workforce impacts of our two options. We take our runcut numbers from above and use them to estimate the number of operators that are required.

	8-Hour	10-Hour
Total Weekly Runs	66.7	52.6
Days Worked Per Week	5	4
Operators Required	13.3	13.2

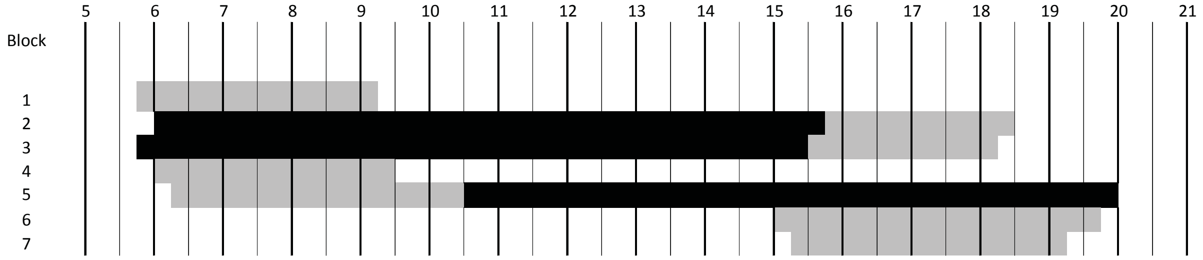
And the answer is the same! Taking a step back like this makes sense, as with either 5-8 hour or 4-10 hour workweeks the total number of worked hours is 40. The table does show a mathematical reduction of 0.1 operators required (less than 1%), but this does not necessarily translate into any real workforce reductions.

The implication here is that 4-10 workweeks do not result in reduced labor requirements. The basic tenet is that the total number of operators required is a function of how much work is undertaken in a week, not in a given runcut. The reduced numbers in a runcut therefore need to be considered against the total days worked.

Runcut Impacts

Further consideration is required into how 10-hour (or any longer) runs affect the runcut. As with many runcut issues, this is a function of many inputs.

Let's return to our original Line 97 blocks and consider the potential to create 10-hour runs.



Here there are three 10-hour straight runs highlighted. But notice the effect on the rest of the runcut. We are left with seven shorter pieces to make into split or part-time runs. In this case, spread limits constrain the number of split runs to at most two, leaving us with three part-time runs. The impact of the 10-hour runs in this case is to increase the number of shorter part-time runs to three. This may or may not be a desirable outcome. Our total number of runs remains at eight (three straight, two split, and three part-time), yet when it comes to rostering/bidding there will actually be an additional operator required (as the 10-hour runs will be covered by operators working only four days).

In this case the answer is probably that 10-hour runs, combined with four-day workweeks, would result in an efficiency loss. However there are many cases where 10-hour runs and 4-day workweeks may be appropriate. Again the key driver of efficiencies through this approach is the reduction in nonproductive time in the runcut (primarily travel and sign-on/clear time) through fewer total runs.

Issues with 10-Hour Runs

The discussion above has covered some of the impacts of 10-hour runs, whether combined with 4-day workweeks or not. Below are some further issues to consider when creating 10-hour runs.

- **A longer span of service, with a higher level of off-peak service, tends to lessen the runcut impact of 10-hour runs.** For example if all blocks are only 14-hours long, cutting 10-hour pieces limits the number of straight runs that can be created (as in the above example). However longer blocks reduce this impact. Eighteen-hour blocks allow one 10-hour run and one eight-hour straight run to be created, for example.

- **A larger runcut generally provides more options for "the rest of the runcut" if 10-hour runs are applied.** Simply put, higher volume in the runcut allows more options for the remaining pieces.
- **Typically there will be limitations on the number of 10-hour runs that can be created.** As a rule of thumb it would be rare for more than 20% of runs to be of the 10-hour type.
- **10-hour runs should incorporate the same philosophy as eight-hour runs, where possible.** That is, there should be a balance between runs over 10 hours and under 10 hours. However in some circumstances driving time limits (in some cases set at 10 hours) limit this capability. In this case guarantee time should be avoided and runs cut as close to 10 hours as possible.
- **Split runs are difficult to increase in length at their extremities** (i.e., before the AM Peak and after the PM peak) due to spread constraints, meaning that 10-hour splits will tend to creep into the off-peak periods between 9 AM and 11 AM and 1 PM and 3 PM. This becomes less feasible if the off-peak service levels are low and can also reduce the number of straight runs. However, it is generally difficult to build longer split runs, and use of 10-hour splits often leads to an increase in make-up time (assuming a guarantee of 10 hours).
- **Work rules at many systems allow for the creation of longer (up to 10-hour) runs as part of a normal five-day workweek.** Whether such runs are efficient depends upon the overtime approach adopted (see the earlier discussion on optimized overtime). The decision to apply 10-hour runs to four-day workweeks is as much a rostering and workforce utilization issue as it is a runcut issue.
- **Longer runs can have operational and absence coverage impacts.** For example an operator who works a 6 AM to 2 PM straight run may be available to cover a school tripper or short PM block as overtime, possibly to cover an unscheduled absence. However if the work day is longer there may be less opportunity for such coverage, or safety issues through longer driving times may arise.
- **There are potential safety impacts of operators working longer runs.** Your agency should have some data on any link between longer daily driving hours and accidents, for example.

D. Workforce Utilization

The three preceding sections have each covered aspects of workforce utilization. The runcut can affect workforce utilization through the mix of run types applied, by the length of runs created, and by creating a runcut that allows for rosters to be built effectively. While each of the three discussions was presented in isolation, the tradeoffs between overtime, part-time operators, and 10-hour runs are made interactively by schedulers when creating runcuts.

Workforce utilization from a scheduler's perspective relates to how the runs and rosters are built to apply the available labor resources most efficiently, within the constraints provided by contracts and work rules. In this sense it relates not only to the scheduled cost of the runcut but also how this translates to extraboard utilization, absenteeism management, and unscheduled overtime.

In the preceding discussions we have noted a strong link between the makeup of the runcut/rosters and the management of labor in terms of levels of absenteeism and unscheduled overtime. There are certainly no prescriptive answers here. Below we note some of the factors that influence how effectively the planned runcut translates into efficient operations:

- The current labor market
- Agency-specific wage rates
- How the roster is constructed, e.g., is weekend work rostered or left as uncovered for overtime?
- Are trippers created? If so, are they left uncovered for overtime, or assigned to the extraboard?
- What is the size of the extraboard?

E. Cost, Complexity, and Quality

A good scheduler understands that at times there are tradeoffs between the overall cost of a runcut and the complexity of the runs created. We have touched on this topic repeatedly throughout the manual, as we covered issues including:

- **Interlining.** There can be a tradeoff between the amount of interlining and the cost of the solution.
- **Garage assignments.** Keeping garage assignments simple may result in additional deadhead mileage and hours.
- **Run Types.** In particular the use of part-time and 10-hour runs can affect efficiency levels and operational complexity.
- **Reliefs.** We have covered in detail the potential to use different relief types, at differing levels of complexity, to achieve a range of outcomes.

- **Multipiece runs,** which allow potential for improved efficiencies but represent a more challenging operational outcome.
- **Meals.** Having meal breaks in runs, however handled, makes the runcut and the operation more complex. Meals can be created in a manner that reduces this complexity.
- **Events and exceptions,** which can be scheduled in a manner conducive to consistency of operation from one period to the next.

In all aspects of scheduling the scheduler is attempting to create operationally sound and efficient runcuts. The important consideration here is that these are not mutually exclusive outcomes.

The section below notes the ability of computerized systems to produce improved quality outcomes for the same efficiency levels. What does this mean? It means that the scheduler should not only model cost constraints and work rules but also quality and operational preferences. These can then be considered as part of the runcutting solution as well.

Consider a case where we have two split runs with spreads of 13:00 and 11:00, and maximum of 13:00 allowed in the labor agreement. By swapping the PM pieces we could end up with two 12-hour spreads. The cost of the spread premium is the same but now we have a potentially better outcome. The computerized system can be told this—that we prefer equalized spreads or fewer spreads close to the maximum limit. We can then run an option with this limit and without this limit, and see if there is any discernable change in efficiency levels.

F. Computerized Scheduling Revisited

During the course of previous sections we have noted the capacity of computerized scheduling systems to assist in and improve the scheduling process.

Our overall observation is that the widespread introduction of computerized systems has resulted in efficiency gains, particularly in larger systems where the size of the runcutting problem means the sheer computational power of the computer provides better solutions.

When undertaking runcutting, there are several approaches that need to be applied in order to best harness the computational power of the system and work within the needs of operational outcomes. Some of these are noted below.

- **Understand the solution that the system should be trying to achieve.** Consider some of the approaches we have discussed here and get to know what the solution should be, before the computer generates one.

- **Test the rules by manually creating, within the system, various types of runs.** Make sure these are legal and are costed correctly. The system must be able to accurately create and cost runs according to the rules provided, and this calibration step is critical. The rules should be tested and refined with a "one-at-a-time" approach to ensure each aspect of the labor agreement is accurately modeled.
- **The first solution is not the best solution—ever.** "Push button" scheduling is never an option for producing quality schedules, runcuts, or rosters. In every scheduling solution there is potential for improvement, whether created manually or by the computer. Create solutions, tweak the rules or parameters, fix some preferred runs—do any of these and recreate the solution, always looking for improvement. Running 20 or 50 versions of a solution is not uncommon, nor is it unreasonable.
- **Use the interactive tools provided.** Some systems provide excellent tools for a scheduler to create a runcut interactively, without submitting an automatic solution. The ability to cut pieces, form runs, and see results as the runcut develops is extremely powerful in the hands of an experienced scheduler.
- **Reconsider the rules/parameters/constraints for each new runcut.** Schedulers can fall into the habit of a "set and forget" approach to rules as defined in a computerized system. For every new sign-up, there are likely to be changes to the trips, blocks, or even work rules. Consider how these have changed and adjust the system accordingly. Recall objectives that could not be achieved last time and attempt to achieve them this time.
- **Start with simple rules.** Do not overconstrain a system in the first instance. Start by putting in only basic "hard" rules—durations, counts, limits. Do not decide things for the system if you are not sure of the outcome. Then start to add in constraints and changes to penalties or weightings, preferably one at a time. Build up a more complex set of rules as you go.
- **Carefully consider every rule, parameter, and constraint.** Each rule is effectively a line of code that will have a value assigned during an automated runcut. Each rule is therefore like writing a line of computer code. Make sure the rule has the desired impact by changing only that rule and recreating the solution.
- **Look for solutions that allow improved quality within the same resource requirements or total costs.** Once you are satisfied with the costing levels (number of runs, paid hours, etc.) look to improve the quality of the runcut. This can be both the operational quality (simplicity is generally better) and the quality of life for operators. These outcomes are not mutually exclusive, and a good scheduler will be aware of how far a system can be used to provide these multiple outcomes.

Note that many of these suggestions hold true for both computerized and noncomputerized scheduling processes. Even the most sophisticated computer system still requires review and hands-on involvement of the scheduler, who can make adjustments throughout the automated process to enhance both the quality and the efficiency of the outcome.

LEVEL 3

End of Advanced Runcutting.

Rostering continues on the next page.

Chapter 6.
Rostering

rostering

The process of grouping daily operator runs into packages of weekly work assignments. The finished product is known as a roster or a bid package.

sign-up

The process in which operators select work assignments. Most agencies have three or four sign-ups each year. Sign-up is also called “bid,” “line-up,” “pick,” “shake-up,” and “mark-up.”

sign-up or bid period

The period of time that a specific sign-up is in effect, usually three or four months.

6.1 Basic Rostering—Rosters and Their Purpose

LEVEL
1

Rostering is the process of grouping daily operator runs into packages of weekly work assignments. Operators are generally given the opportunity, based on order of seniority, to pick their work for the next period of time. This period of time is often called a **sign-up period** or **bid period**. At most agencies, sign-ups generally occur three or four times a year, so the bid period might last for three or four months.

Rosters have a list of work assignments, indicated in the example below by the roster number. Assignments may include mixtures of runs, such as:

- Weekday runs only
- Weekday runs and a Saturday run
- Weekday runs and a Sunday run
- Weekday runs, a Saturday run, and a Sunday run

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Weekly Pay Hours
1001	Off	101 8:00	101 8:00	101 8:00	101 8:00	101 8:00	Off	40:00
1002	Off	102 8:00	102 8:00	102 8:00	102 8:00	102 8:00	Off	40:00
1003	701 10:00	103 10:00	103 10:00	103 10:00	Off	Off	Off	40:00
1004	Off	Off	104 10:00	104 10:00	104 10:00	104 10:00	Off	40:00
1005	Off	105 8:00	105 8:00	105 8:00	105 8:00	105 8:00	Off	40:00
1006	Off	104 10:00	Off	Off	103 10:00	103 10:00	601 10:00	40:00

In the example, roster numbers are four digits and all run numbers are three digits. Weekday runs begin with 1, Saturday runs begin with 6, and Sunday runs begin with 7. Each agency has its own numbering convention.

Weekly work assignments typically include five daily runs, each close to or over eight hours. Some agencies use 10-hour daily runs, in which case the roster would also include assignments with four daily 10-hour runs (see Roster No. 1003 and 1004 in the example). Normally, these runs are not allowed to go too far over 10 hours per day.

Rosters generally remain in effect throughout the sign-up period. In the event that a roster is permanently vacated, the agency may hold a **line pick** in between scheduled sign-ups to fill the roster. Typically, only operators with less seniority than the prior holder of the vacated roster are eligible to bid. A line pick may also be held on one route only if there have been significant schedule changes to the route during the sign-up period. Minor changes to a trip or series of trips made during the sign-up period (due to detours or minor running time problems) are usually addressed by means of a **"patch"** or temporary modification. An agency's labor agreement may restrict the conditions under which a patch can be used.

Larger agencies operating out of multiple garages may also hold a **system sign-up**. This provides operators an opportunity to transfer to another garage. Typically, one scheduled sign-up during the year may be designated as a system sign-up.

Types of Rosters

Building a roster of weekly work is carried out in one of two ways, depending on agency policy and work rules:

- agency-developed rosters, built by the schedulers
- operator-developed rosters (also known as cafeteria-style rostering), assembled by individual operators at the time of bidding based on their seniority

Agency-Developed Rostering

The roster shown above is an example of an agency-developed roster. The agency packages daily runs and days off into a weekly work assignment. Operators then pick their work from the list of weekly rosters.

When developing a roster under this scenario the scheduler is trying to achieve a number of outcomes, including:

- Meet the requirements of the labor agreement. As always this is the highest and most stringent consideration. Typically the labor agreement will mandate areas including number of days worked, minimum/maximum weekly (or period) hours, days off requirements, minimum rest breaks, run type limitations, etc.
- Achieve high levels of efficiency. This outcome can be defined in a number of ways but probably will include minimizing operator requirements (defined as roster lines), and minimizing pay hours.
- Meet operator preferences inclusive of days off patterns, types of runs operated, rest breaks, and other working conditions.

line pick

A sign-up held in between scheduled sign-ups to fill one or more runs permanently vacated due to illness, disability, or termination. Only operators with less seniority than the prior holder of the vacated run are eligible to bid. Also, a special sign-up held on one route only due to a significant schedule change during the sign-up period on the route.

patch

A temporary modification to a trip or series of trips on a route implemented during the sign-up period to account for a detour or to address minor running time problems.

system sign-up

A scheduled sign-up during which operators may transfer from one garage to another. System sign-ups are usually held no more than once a year. At intermodal agencies, the system sign-up may allow an operator to transfer between modes as well.

As is often the case, the scheduler is trying to balance efficiency requirements against preferred working conditions.

Agency-developed rosters may be simple one-run patterns or may be complex combinations of runs, days off, and patterns.

Cafeteria-style or Operator-Developed Rostering

In **cafeteria-style rostering**, an operator can choose both *specific daily runs* and *days off* from a master list of all runs and all available days off. The name comes from how customers in a cafeteria choose individual food items that make up their meal.

The schedule department will develop and **post** a **Master Run List** containing all weekday, Saturday, and Sunday runs and a master list of available days off for the sign-up. In reality the schedule department is primarily an administrator of the rostering process under this scenario, as opposed to having responsibility for creation or development of the rosters.

The example of master lists shown below uses the same numbering scheme for runs as in the previous example. The list of available days off shows the total number of days off that may be chosen for each day of the week.

Note that in the master lists, runs and days off are listed separately for four-day and five-day rosters. Some transit systems that use cafeteria ros-

MASTER RUN LIST AND MASTER DAYS OFF LIST

Weekday Runs		Saturday Runs		Sunday Runs	
Run #	Pay hours	Run #	Pay hours	Run #	Pay hours
101	8:00	601	10:00	701	10:00
102	8:00	602	8:45	702	8:00
103	10:00	603	8:15	703	8:21
104	10:00	604	8:00		
105	8:00				
106	8:22				
107	8:45				

Available Runs - Five Day Rosters

Sun	Mon	Tue	Wed	Thu	Fri	Sat
702	101	101	101	101	101	602
703	102	102	102	102	102	603
	105	105	105	105	105	604
	106	106	106	106	106	
	107	107	107	107	107	

Available Days Off - Five Day Rosters

Sun	Mon	Tue	Wed	Thu	Fri	Sat
4	1	1	1	1	1	3

Available Runs - Four Day Rosters

Sun	Mon	Tue	Wed	Thu	Fri	Sat
701	103	103	103	103	103	601
	104	104	104	104	104	

Available Days Off - Four Day Rosters

Sun	Mon	Tue	Wed	Thu	Fri	Sat
2	1	1	1	1	1	2

agency-developed rostering

The process in which the transit agency packages daily runs into weekly work schedules or rosters in advance of the sign-up. The operators then select from the prepared rosters.

cafeteria-style rostering

The process in which operators create their own rosters by selecting daily runs and days off from a master list.

master run list

A list containing all weekday, Saturday, and Sunday runs. The Master Run List may be the Run Guide or some variation of the Run Guide. Typically used in cafeteria rostering.

posting

Notification to operators of all work assignments that will be available for selection during the next sign-up. Runs are posted for cafeteria rostering; rosters are posted for agency-developed rostering. Runs and rosters are posted for a number of days prior to the start of actual bidding to provide time for operators to study their options prior to making their selection.

tering and have both 5/8 and 4/10 rosters have agreements with their unions to use agency-developed rosters for the 4/10s, because cafeteria rostering does not always work well for 4/10s.

In addition, a master list of available **extraboard** (relief, **stand-by**) assignments is posted along with a master list of eligible operators. The operator list is typically sorted in order of descending seniority and includes the day and time of each operator's turn to pick listed next to his or her name. Picking runs and days off can be as simple as initialing the desired run and days off on the master lists.

Schedule and/or operations department personnel, and sometimes Union personnel, usually "officiate" during the sign-up to ensure that operators pick work according to the seniority list and that all rules governing the cafeteria roster and sign-up process are followed.

There are several variations within cafeteria-style rostering, often based on specific constraining elements of the labor agreement or past practice. Constraints can include:

- Days off must be consecutive unless consecutive days are no longer available.
- Routes cannot be mixed during the work week if the same route is available for all days.
- Run types (straight/split) cannot be mixed until necessary to form a full weekly assignment.
- A minimum number of off-duty hours must separate each run picked.

Implications of Each Approach

Agencies that use cafeteria rostering believe that operators are more conscientious about the quality of their work when they have more control over their work hours and assignments. This can translate into non-quantifiable benefits such as good customer relations as well as into quantifiable benefits such as lower absenteeism, reduced worker compensation claims, and fewer accidents.

Under cafeteria rostering, senior operators often pick runs greater than eight hours in length to qualify for more overtime pay. Since senior operators usually earn the most and pick first; this can increase agency costs and leave junior operators with runs that pay eight hours or less. As a result, some senior operators earn high levels of weekly overtime while junior operators are left with weekly assignments that pay less than 40 hours. If there is a 40-hour paid weekly guarantee, the transit agency ends up paying more **make-up time**.

A significant issue related to cafeteria-style rostering can be that while the senior operators (i.e., those who get to pick the work first) are able to achieve their preferences, the less senior operators tend to have the "leftover" less-desirable work days from which to construct their

extraboard

A group of operators who provide coverage of vacant runs and other work on a daily or weekly basis. Operators may pick the extraboard during a sign-up or may be assigned to the extraboard if no more runs are available.

stand-by time

Time that an operator spends at the garage at the agency's direction awaiting assignment of a run or a piece of work. Usually associated with a report by an extraboard operator, stand-by is intended to provide a pool of operators that will be available to fill runs vacated by unscheduled absences.

make-up time

Time added to an operator's work hours to bring the total up to the guaranteed minimum (usually eight hours per day or 40 hours per week). Full-time operators often have an eight-hour guarantee, even if their runs are short of eight hours.

Tip If your property uses a cafeteria-style bid, it is important to monitor to ensure that the runs being selected are "legal" and follow the rules established by your contract and practice. Errors allowed in bidding may result in costly rebids.

Tip Many transit agencies roster the work for drivers in advance and let drivers "bid" or pick work from runs that have already been packaged into a weekly work schedule or roster. Other agencies let drivers pick individual daily assignments. If your agency rosters work in advance, it is important for you to know the policy on the number of straight and split runs, consecutive days off, and other work rules that impact the roster.

Tip An agency can achieve significant cost savings using agency-developed rostering if make-up pay and overtime pay are calculated on a weekly basis.

workweeks—late runs, weekend work, lower-paying runs, etc. This can lead to a trend of higher turnover of less senior staff.

Systems that use agency-developed rostering argue that preassembled rosters can be developed in a more cost-effective manner and thus save money. This is especially true for agencies with no daily guarantee of eight hours pay and with weekly instead of daily overtime pay. In these cases, the agency can combine runs of over eight hours with runs of under eight hours into a weekly assignment of 40 hours, thus minimizing overtime and make-up pay.

The example below shows potential cost savings for an agency using agency-developed rostering without a daily guarantee and daily overtime. One long run of 8:40 can be combined with four smaller runs to achieve a weekly assignment of 40 hours with no overtime and no make-up pay.

Savings can be accrued even if overtime is calculated daily. In the example, if daily overtime is paid (at time and a half) but there is no daily guarantee, then total pay hours would be 40:20.

ROSTER WITH DAILY MAKE-UP AND DAILY OVERTIME

Time	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Weekly Total
Platform	Off	Off	7:50	7:50	7:50	7:50	8:40	
Guarantee			0:10	0:10	0:10	0:10		
Overtime							0:20	
Pay Hours			8:00	8:00	8:00	8:00	9:00	41:00

ROSTER WITH WEEKLY MAKE-UP AND WEEKLY OVERTIME

Time	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Weekly Total
Platform	Off	Off	7:50	7:50	7:50	7:50	8:40	
Guarantee								
Overtime								
Pay Hours			7:50	7:50	7:50	7:50	8:40	40:00

In the absence of daily guarantees and overtime, savings are possible with cafeteria rostering. However, these savings would occur randomly and would not reach the potential savings associated with agency-developed rostering.

Roster Examples

This section provides examples of rosters using the Route 97 example from previous chapters. Both agency-developed and cafeteria rosters are shown.

The basic section of the runcutting chapter (Chapter 5) prepared a run guide for Route 97. This will serve as our starting point in developing rosters. The run guide is shown below.

Option 1 - Completed Run Cut

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Travel Hours	Total Hours	Spread	Guarantee	Overtime	Spread Penalty	Paid Hours	Pay/ Plat
				Time	Place	Type	Time	Place	Type											
101	Str	2	5:46	6:01	Garage	Pull	12:09	A	Street	12:34	6:08	0:30	0:10	6:48	6:48	1:12	0:00:00	0:00:00	8:00:00	1.304
102	Str	2	11:44	12:09	A	Street	18:38	Garage	Pull	18:53	6:29	0:30	0:10	7:09	7:09	0:51	0:00:00	0:00:00	8:00:00	1.234
103	Str	3	5:35	5:50	Garage	Pull	12:39	A	Street	13:04	6:49	0:30	0:10	7:29	7:29	0:31	0:00:00	0:00:00	8:00:00	1.174
104	Str	3	12:14	12:39	A	Street	18:19	Garage	Pull	18:34	5:40	0:30	0:10	6:20	6:20	1:40	0:00:00	0:00:00	8:00:00	1.412
105	Str	5	6:05	6:20	Garage	Pull	13:09	A	Street	13:34	6:49	0:30	0:10	7:29	7:29	0:31	0:00:00	0:00:00	8:00:00	1.174
106	Str	5	12:44	13:09	A	Street	19:53	Garage	Pull	20:08	6:44	0:30	0:10	7:24	7:24	0:36	0:00:00	0:00:00	8:00:00	1.188
107	Spl	1	5:31	5:46	Garage	Pull	9:19	Garage	Pull	9:24	8:21	0:50	0:00	9:11	14:18	0:00	0:35:30	2:09:00	11:55:30	1.428
		6	14:46	15:01	Garage	Pull	19:49	Garage	Pull	20:04										
108	Pt	4	5:50	6:05	Garage	Pull	9:38	Garage	Pull	9:53	3:33	0:30	0:00	4:03	4:03	0:00	0:00:00	0:00:00	4:03:00	1.141
109	Pt	7	15:05	15:20	Garage	Pull	19:19	Garage	Pull	19:34	3:59	0:30	0:00	4:29	4:29	0:00	0:00:00	0:00:00	4:29:00	1.126
											54:32	**4:50**	**1:00**	**60:21**		**5:21**	**0:35**	**2:09**	**68:27**	**1.255**

Because Route 97 operates only on weekdays, available days off are on Saturdays and Sundays only. In this example and for weekday-only service in general, the number of available days off on Saturday and on Sunday is equal to the number of weekday runs that may be picked by operators.

One of the important factors that rostering tells us is how many operators we need. The table below shows a formula for computing the total number of operators needed and the number of available days off by day. This table uses a hypothetical number of daily, Saturday, and Sunday runs.

Tip Calculate the number of operators you will need.

(Number of Weekday Runs x 5 +
Number of Saturday Runs +
Number of Sunday Runs) /

5 Day Work Week =
Number of Operators Required

OPERATORS REQUIRED FOR 8-HOUR RUNS

Day	# daily runs	# days per week	Weekly total (daily runs * days)
Weekdays (M-F)	120	5	600
Saturdays	54	1	54
Sundays	26	1	26
Weekly Total			680
Total Operators (weekly total runs / 5 days of work per operator)			136

DISTRIBUTION OF DAYS OFF

	Total # operators	# daily runs	Operators off each day (# operators - # daily runs)
Weekdays (M-F)	136	120	16
Saturdays	136	54	82
Sundays	136	26	110
Weekly Total (weekdays * 5 + Saturday + Sunday)			272

OPERATORS REQUIRED FOR 10-HOUR RUNS

Day	# daily runs	# days per week	Weekly total (daily runs * days)
Weekdays (M-F)	100	5	500
Saturdays	40	1	40
Sundays	40	1	40
Weekly Total			580
Total Operators (weekly total runs / 4 days of work per operator)			145

DISTRIBUTION OF DAYS OFF

	Total # operators	# daily runs	Operators off each day (# operators - # daily runs)
Weekdays (M-F)	145	100	45
Saturdays	145	40	105
Sundays	145	40	105
Weekly Total (weekdays * 5 + Saturday + Sunday)			435

Note that in the eight-hour example, it would not be possible to supply each operator with consecutive days off (which is a requirement in the contracts of most moderate- to large-sized systems). The reason is the difference between the number of Saturday runs and Sunday runs. In this case, the difference is 28 (54 Saturdays minus 26 Sundays). We have already calculated that 16 operators will be off each weekday. (Note the 16 operators off each weekday, or calculated another way, the 54 Saturday runs plus 26 Sunday runs would equal 80 pieces of work on weekends that must be accounted for in days off. This number is divided by 5, the number of days each relief operator will work each week, to equal the 16.) Since 16 is less than 28, 12 runs will have to have split days off. If the union contract does not allow this, the sole alternative, which is expensive, may be to detail 12 runs on Saturday to the extraboard or allow them to be bid by operators on their days off at overtime. The use of part-time operators to cover the open Saturday runs may be another option, contingent upon the labor agreement. The lesson here is to make sure your transit system does not get out of balance in the amount of service provided on Saturday versus Sunday.

Applying these formulas to Route 97, with nine weekday runs and no weekend service:

OPERATORS REQUIRED FOR 8-HOUR RUNS ON ROUTE 97

Day	# daily runs	# days per week	Weekly total (daily runs * days)
Weekdays (M-F)	9	5	45
Saturdays	0	1	0
Sundays	0	1	0
Weekly Total			45
Total Operators (weekly total runs / 5 days of work per operator)			9

DISTRIBUTION OF DAYS OFF

	Total # operators	# daily runs	Operators off each day (# operators - # daily runs)
Weekdays (M-F)	9	9	0
Saturdays	9	0	9
Sundays	9	0	9
Weekly Total (weekdays * 5 + Saturday + Sunday)			18

We can check this total by multiplying the number of operators (9) by the number of days off per week required by each (2) to equal the weekly total of operator days off (18).

Tip To calculate the number of days off required in a given week.

Total days off = Number of Operators required x Number of days off per week

In a traditional five-day work week the number of days off per week is two.

line of work

A weekly work package, developed during rostering, that comprises a fixed set of runs and days off for a set workweek.

rotating (rotary) roster

A roster where operators cycle through the weekly Lines of Work over the course of the sign-up period.

Agency-Developed Rosters

As stated above, under the agency-developed rostering approach, operators pick their weekly work from a master list of weekly rosters, **"Lines of Work**." An agency will typically consider several variations before deciding on the final master list to post. Agency-developed rosters typically have an operator work the same workweek repeatedly, but operators can also cycle through more than one line of work over the course of the sign-up period.

The fixed workweeks (Lines of Work) may also allow the introduction of a **Rotating Roster**, where the operators cycle through the Lines of Work on a weekly (or other) rotation.

A common convention for the format used for the master list of weekly rosters is shown here:

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Weekly Work Hours
1001	Off	# x:xx	# x:xx	# x:xx	# x:xx	# x:xx	Off	xx:xx

Under this numbering convention, a 1000 series number is used as the weekly roster number to avoid confusion with the numbers used to represent daily runs. "#" represents the daily run number under each day of the week, and "x:xx" represents the work hours associated with the run. Daily work hours can be summed across days to obtain weekly work hours. If preferred, pay hours can be substituted for work hours.

As with many of the processes described throughout this manual the potential exists to use either "automated" or "manual" methods. Automated methods refer to use of computerized scheduling systems to develop rosters, based on a range of user-defined inputs. Manual in this context assumes the use of spreadsheets to assist in development of rosters. The level of sophistication of the spreadsheet depends upon user spreadsheet experience/competence. We will discuss further how rosters can be enhanced by at least some basic spreadsheet automation.

Our first effort at developing a roster for Route 97 might look like this:

ROSTER - Route 97 (variation 1)

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Weekly Hours	Make-up Hours	Overtime	Spread Hours	Weekly Pay Hours
1001	Off	101	101	101	101	101	Off					
		6:48	6:48	6:48	6:48	6:48		34:00:00	6:00	0:00:00	0:00:00	40:00:00
1002	Off	102	102	102	102	102	Off					
		7:09	7:09	7:09	7:09	7:09		35:45:00	4:15	0:00:00	0:00:00	40:00:00
1003	Off	103	103	103	103	103	Off					
		7:29	7:29	7:29	7:29	7:29		37:25:00	2:35	0:00:00	0:00:00	40:00:00
1004	Off	104	104	104	104	104	Off					
		6:20	6:20	6:20	6:20	6:20		31:40:00	8:20	0:00:00	0:00:00	40:00:00
1005	Off	105	105	105	105	105	Off					
		7:29	7:29	7:29	7:29	7:29		37:25:00	2:35	0:00:00	0:00:00	40:00:00
1006	Off	106	106	106	106	106	Off					
		7:24	7:24	7:24	7:24	7:24		37:00:00	3:00	0:00:00	0:00:00	40:00:00
1007	Off	107	107	107	107	107	Off					
		9:11	9:11	9:11	9:11	9:11		45:55:00	0:00	2:57:30	10:45:00	59:37:30
1008	Off	108	108	108	108	108	Off					
		4:03	4:03	4:03	4:03	4:03		20:15:00	0:00	0:00:00	0:00:00	20:15:00
1009	Off	109	109	109	109	109	Off					
		4:29	4:29	4:29	4:29	4:29		22:25:00	0:00	0:00:00	0:00:00	22:25:00
Total								301:50:00	26:45:00	2:57:30	10:45:00	342:17:30

This roster features consistent runs in each assignment. Rosters 1001 through 1007 are full-time rosters, while Rosters 1008 and 1009 are part-time rosters. There is an extensive amount of make-up time in this roster, but because this example draws from only one route, there are fewer options for hooking trips and cutting runs.

Are there any "tweaks" that we could make to this roster to enhance efficiency? If the primary concern were high levels of overtime, then addition of 4/10 work assignments would be worth exploring. To digress for a moment, overtime is not necessarily a bad thing, since it can minimize the number of operators. Arguments in favor of minimizing the number of operators include:

- Fewer operators translate to lower costs for benefits such as medical premiums and pension obligations.
- In good economic times when jobs are plentiful, it is often difficult to recruit a sufficient number of operators.

Tip Generally the best rosters have as many runs close to the eight-hour daily target as possible. However, every property is different, and it is always important to understand your property's work rules before you move to rostering.

Minimizing the number of operators translates directly to developing rosters with higher levels of overtime. The tradeoff is often seen in purely economic terms: the added cost of benefits for a new operator versus higher overtime costs.

There is also an important argument against minimizing the number of operators:

- Longer work hours can potentially result in increased number of accidents (due to fatigue behind the wheel) and increased absenteeism.

Another possible change is to mix and match daily runs to bring each roster as close to 40 weekly pay hours as possible. This alternative, shown as variation 2, assumes that overtime and make-up time are paid on a weekly, not a daily, basis.

ROSTER - Route 97 (variation 2 - weekly overtime and make-up)

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Weekly Hours	Make-up Hours	Overtime	Spread Hours	Weekly Pay Hours
1001	Off	101	101	101	101	101	Off					
		6:48	6:48	6:48	6:48	6:48		34:00:00	6:00	0:00:00	0:00:00	40:00:00
1002	Off	102	102	102	102	102	Off					
		7:09	7:09	7:09	7:09	7:09		35:45:00	4:15	0:00:00	0:00:00	40:00:00
1003	Off	103	103	103	103	103	Off					
		7:29	7:29	7:29	7:29	7:29		37:25:00	2:35	0:00:00	0:00:00	40:00:00
1004	Off	107	107	104	104	104	Off					
		9:11	9:11	6:20	6:20	6:20		37:22:00	2:38	0:00:00	4:18:00	44:18:00
1005	Off	105	105	105	105	107	Off					
		7:29	7:29	7:29	7:29	9:11		39:07:00	0:53	0:00:00	2:09:00	42:09:00
1006	Off	106	106	106	106	106	Off					
		7:24	7:24	7:24	7:24	7:24		37:00:00	3:00	0:00:00	0:00:00	40:00:00
1007	Off	104	104	107	107	105	Off					
		6:20	6:20	9:11	9:11	7:29		38:31:00	1:29	0:00:00	4:18:00	44:18:00
1008	Off	108	108	108	108	108	Off					
		4:03	4:03	4:03	4:03	4:03		20:15:00	0:00	0:00:00	0:00:00	20:15:00
1009	Off	109	109	109	109	109	Off					
		4:29	4:29	4:29	4:29	4:29		22:25:00	0:00	0:00:00	0:00:00	22:25:00
Total								301:50:00	20:50:00	0:00:00	10:45:00	333:25:00

The shortest full-time work assignment in variation 2 is 34:00, compared to 31:40 in variation 1, and no roster involves work in excess of 40 hours per week.

Why does weekly overtime and make-up time make a difference? Variation 3 shows the same roster as variation 2, but with daily overtime and make-up pay. Compare Roster 1007 in both examples. In variation 2, the combination of runs over and under eight hours results in no overtime, since weekly hours do not exceed 40, and only 1:29 in make-up time. In variation 3, the agency must pay overtime for Run 7 on Wednesday and Thursday (total overtime of 2:22 hours, which translates to an additional 1:11 pay hours), and must pay make-up time for the other days (1:40 on Monday and Tuesday and 0:31 on Friday for a total of 3:51 in make-up time). Totals in variation 3 are identical to variation 1.

ROSTER - Route 97 (variation 3 - daily overtime and make-up)

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Weekly Hours	Make-up Hours	Overtime	Spread Hours	Weekly Pay Hours
1001	Off	101	101	101	101	101	Off					
		6:48	6:48	6:48	6:48	6:48		34:00:00	6:00	0:00:00	0:00:00	40:00:00
1002	Off	102	102	102	102	102	Off					
		7:09	7:09	7:09	7:09	7:09		35:45:00	4:15	0:00:00	0:00:00	40:00:00
1003	Off	103	103	103	103	103	Off					
		7:29	7:29	7:29	7:29	7:29		37:25:00	2:35	0:00:00	0:00:00	40:00:00
1004	Off	107	107	104	104	104	Off					
		9:11	9:11	6:20	6:20	6:20		37:22:00	5:00	1:11:00	4:18:00	47:51:00
1005	Off	105	105	105	105	107	Off					
		7:29	7:29	7:29	7:29	9:11		39:07:00	2:04	0:35:30	2:09:00	43:55:30
1006	Off	106	106	106	106	106	Off					
		7:24	7:24	7:24	7:24	7:24		37:00:00	3:00	0:00:00	0:00:00	40:00:00
1007	Off	104	104	107	107	105	Off					
		6:20	6:20	9:11	9:11	7:29		38:31:00	3:51	1:11:00	4:18:00	47:51:00
1008	Off	108	108	108	108	108	Off					
		4:03	4:03	4:03	4:03	4:03		20:15:00	0:00	0:00:00	0:00:00	20:15:00
1009	Off	109	109	109	109	109	Off					
		4:29	4:29	4:29	4:29	4:29		22:25:00	0:00	0:00:00	0:00:00	22:25:00
Total								301:50:00	26:45:00	2:57:30	10:45:00	342:17:30
Pay-to-Platform Ratio												1.255

Many agencies believe that it is important for an operator to work the same weekday run every day. The operator becomes more familiar with the route and also gets to know regular passengers who ride at the same time every day. Agencies supporting this view are willing to accept some additional cost in order to achieve route and passenger familiarity. Variation 2 may or may not be acceptable to such agencies, because only four of the seven full-time rosters are consistent throughout the week. At other agencies, operators may prefer the variety of working different runs or routes to relieve boredom (and the potential of related fatigue). The scheduler should be aware of preferences at his or her specific system.

Union-management relations might also be a factor. The operators' union might prefer rosters featuring work assignments with overtime, or might prefer less overtime and more work assignments. The optimal situation is a union-preferred roster that is the least expensive among various alternatives, but agencies may be willing to accept some additional cost (with the emphasis on "some") to accommodate union preferences.

pay-to-platform ratio

The ratio of pay hours to platform time. For example, if an operator receives 9:00 in pay for 8:00 of platform time, the pay-to-platform ratio is 1.125 (9:00/8:00). The pay-to-platform ratio is one of the most widely used methods of measuring runcut efficiency and is often used to measure the impacts of non-platform items (such as report allowance or relief allowances) on operator pay hours. Some systems use the inverse, the ratio of platform to pay hours.

This brings us to an important point which has been emphasized throughout this manual: the scheduler should be focused on providing the best quality operational outcome for the given cost. This applies strongly to rostering where a number of trade-offs can be made (such as days-off patterns or rest times) to reduce costs, or even to provide a better quality solution within the same costs.

Evaluating the Agency-Developed Rosters

Choosing among roster variations can involve consideration of a number of factors. Before making a final decision, an agency needs to understand fully the cost and operational implications of different rosters.

Comparison charts are frequently used to present quantifiable information to aid in the evaluation of variations. An example comparison chart for the three variations of agency-developed rosters for Route 97 is shown below.

COMPARISON CHART FOR THREE ROSTER VARIATIONS FOR ROUTE 97

	Variation 1	Variation 2	Variation 3
Total hours for all weekly rosters	301:50:00	301:50:00	301:50:00
@ Straight time	295:55:00	301:50:00	295:55:00
@ Overtime (time and a half)	5:55:00	0:00:00	5:55:00
@ Make-up	26:45:00	20:50:00	26:45:00
@ Spread time (half-time over 10 hours)	21:30:00	21:30:00	21:30:00
Pay hours	342:17:30	333:25:00	342:17:30
Number of operators required	9 (7/2)	9 (7/2)	9 (7/2)
Total platform hours	272:40:00	272:40:00	272:40:00
Pay-to-platform ratio	1.255	1.223	1.255

Variation 1 and Variation 3 are identical, as noted earlier. Variation 2 is the least expensive roster, because it has no overtime and less make-up time. Variation 2 results in a savings of 8:52:30 per week. Variation 2 also has the lowest **pay-to-platform ratio**. The number of operators is the same under all three scenarios.

Computerized scheduling systems allow a more qualitative comparison of roster outcomes. Preferred parameters can be quantified to check one solution against the next, without the scheduler having to wade through large tables or columns. The result can be rosters of improved quality which translates to an enhanced work environment for operators.

Cafeteria Rosters

Under the cafeteria rostering approach, operators build their own rosters by picking their weekly work from the master run list and the master days off list. These master lists are either the actual Run Guide shown earlier or derived directly from the Run Guide. The Route 97 Run Guide was shown in the agency-developed rosters example.

The calculations for required number of operators and number of available days off are identical for cafeteria rosters. Runs and days off are posted, and operators make their own weekly assignment by selecting from available runs and available days off.

Cafeteria rostering is simpler for the agency, since it does not have to prepare and evaluate roster alternatives. However, those responsible for the sign-up process must check the numbers of available runs at the end of each day of the sign-up in order to be certain that no run was picked twice or that an odd number of work or days off were left open. The operations department usually manages the sign-up process for cafeteria rostering, so for schedulers, cafeteria rostering often means much less work (the schedules department is invariably responsible for agency-developed rosters). Agencies that use cafeteria rostering consider it a positive in terms of employee morale, since operators design their own work week. The downsides are that (1) the agency cannot count on generating cost savings through effective rostering and (2) less senior operators are often left with very undesirable work weeks.

While there are many arguments pro and con, agencies with weekly but not daily guarantees, should avoid cafeteria rostering if at all possible because of the inefficiencies previously discussed. If there are daily guarantees, then, as indicated above, the choice can be either.

Tip Agencies with weekly (but not) daily guarantees often benefit more from agency-developed rosters and should avoid cafeteria rostering if possible.

LEVEL
1

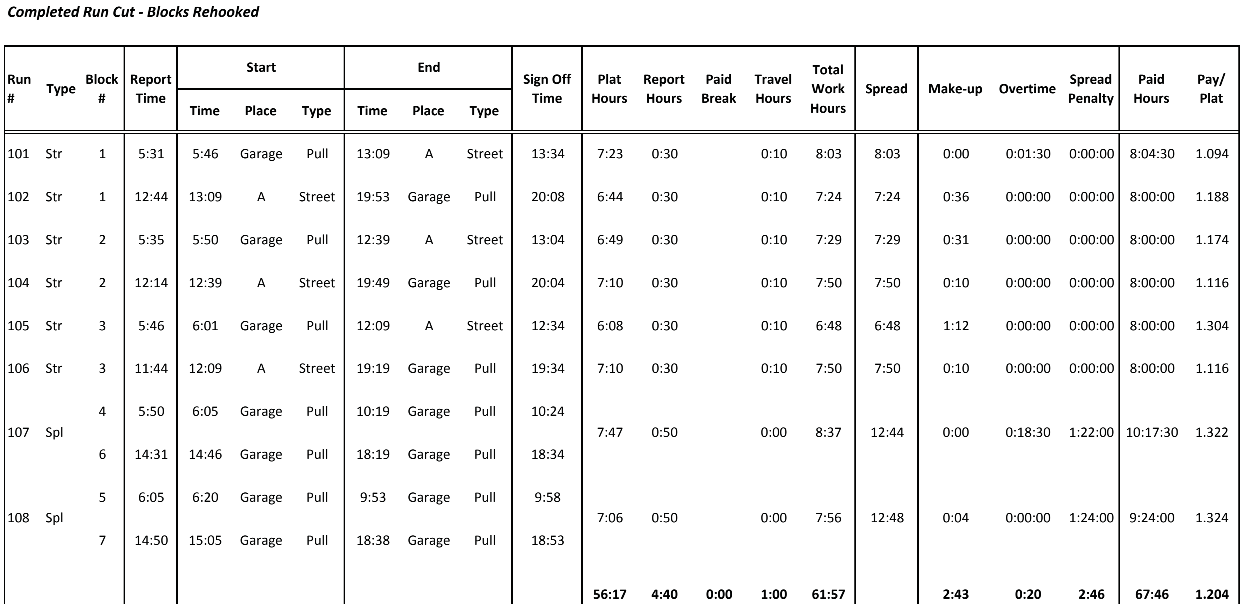
End of Basic Rostering.

The Intermediate Section of Rostering continues on the next page.

To jump to Rail Scheduling, go to page 7-1.

6.2 Intermediate Rostering

The basic section of this chapter set the foundation for rostering using a relatively simple example. In this section, you will develop rosters for Route 97 based on the Run Guide from the intermediate section of Chapter 5: Runcutting (shown below). This Run Guide includes eight full-time runs, as shown below.



Completed Run Cut - Blocks Rehooked

Run #	Type	Block #	Report Time	Start			End			Sign Off Time	Plat Hours	Report Hours	Paid Break	Travel Hours	Total Work Hours	Spread	Make-up	Overtime	Spread Penalty	Paid Hours	Pay/ Plat
				Time	Place	Type	Time	Place	Type												
101	Str	1	5:31	5:46	Garage	Pull	13:09	A	Street	13:34	7:23	0:30		0:10	8:03	8:03	0:00	0:01:30	0:00:00	8:04:30	1.094
102	Str	1	12:44	13:09	A	Street	19:53	Garage	Pull	20:08	6:44	0:30		0:10	7:24	7:24	0:36	0:00:00	0:00:00	8:00:00	1.188
103	Str	2	5:35	5:50	Garage	Pull	12:39	A	Street	13:04	6:49	0:30		0:10	7:29	7:29	0:31	0:00:00	0:00:00	8:00:00	1.174
104	Str	2	12:14	12:39	A	Street	19:49	Garage	Pull	20:04	7:10	0:30		0:10	7:50	7:50	0:10	0:00:00	0:00:00	8:00:00	1.116
105	Str	3	5:46	6:01	Garage	Pull	12:09	A	Street	12:34	6:08	0:30		0:10	6:48	6:48	1:12	0:00:00	0:00:00	8:00:00	1.304
106	Str	3	11:44	12:09	A	Street	19:19	Garage	Pull	19:34	7:10	0:30		0:10	7:50	7:50	0:10	0:00:00	0:00:00	8:00:00	1.116
107	Spl	4	5:50	6:05	Garage	Pull	10:19	Garage	Pull	10:24	7:47	0:50		0:00	8:37	12:44	0:00	0:18:30	1:22:00	10:17:30	1.322
		6	14:31	14:46	Garage	Pull	18:19	Garage	Pull	18:34											
108	Spl	5	6:05	6:20	Garage	Pull	9:53	Garage	Pull	9:58	7:06	0:50		0:00	7:56	12:48	0:04	0:00:00	1:24:00	9:24:00	1.324
		7	14:50	15:05	Garage	Pull	18:38	Garage	Pull	18:53											
											56:17	**4:40**	**0:00**	**1:00**	**61:57**		**2:43**	**0:20**	**2:46**	**67:46**	**1.204**

Cafeteria-style rosters will be considered first, since these are simpler for the scheduler. In a cafeteria system, the scheduler is only responsible for calculating the number of operators needed and the available days off by day of the week. A discussion of agency-developed rosters follows the cafeteria rostering.

Cafeteria Rostering—Weekday-only Service

The Run Guide for Route 97, as shown above, has a total of eight daily runs. In this cafeteria rostering example, assume that the route operates only on weekdays and there are no 4/10 rosters. The formulas for calculating days off and the number of operators required are shown below, yielding the following result:

OPERATORS REQUIRED FOR 8-HOUR RUNS

Day	# daily runs	# days per week	Weekly total (daily runs * days)
Weekdays (M-F)	8	5	40
Saturdays	0	1	0
Sundays	0	1	0
Weekly Total			40
Total Operators (weekly total runs / 5 days of work per operator)			8

DISTRIBUTION OF DAYS OFF

	total # available operators	# daily runs	Operators off each day (# operators - # daily runs)
Weekdays (M-F)	8	8	0
Saturdays	8	0	8
Sundays	8	0	8
Weekly Total (weekdays * 5 + Saturday + Sunday)			16

Operators have no choice but to take Saturday and Sunday as their days off. The most straightforward operating roster that could result from cafeteria-style selection of work assignments would include the same run for each operator Monday through Friday. An example of this weekly roster is shown on the following page, under the assumption that the most senior operators would pick weekly assignments with overtime. Of course, the scheduler cannot predict how the cafeteria roster will look.

CAFETERIA ROSTER - Route 97

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Weekly Hours	Platform Hours
101	Off	07	07	07	07	07	Off		
		10:17	10:17	10:17	10:17	10:17		51:27:30	38:55:00
102	Off	08	08	08	08	08	Off		
		9:24	9:24	9:24	9:24	9:24		47:00:00	35:30:00
103	Off	01	01	01	01	01	Off		
		8:04	8:04	8:04	8:04	8:04		40:22:30	36:55:00
104	Off	05	05	05	05	05	Off		
		8:00	8:00	8:00	8:00	8:00		40:00:00	30:40:00
105	Off	02	02	02	02	02	Off		
		8:00	8:00	8:00	8:00	8:00		40:00:00	33:40:00
106	Off	03	03	03	03	03	Off		
		8:00	8:00	8:00	8:00	8:00		40:00:00	34:05:00
107	Off	04	04	04	04	04	Off		
		8:00	8:00	8:00	8:00	8:00		40:00:00	35:50:00
108	Off	06	06	06	06	06	Off		
		8:00	8:00	8:00	8:00	8:00		40:00:00	35:50:00
							TOTAL WEEKLY HOURS	338:50:00	281:25:00

Cafeteria Rostering—Weekday and Weekend Service

In this example, Route 97 operates seven days a week. Weekend service is the same on Saturday and Sunday in this example, and is about 60% of weekday service. The first step is to determine the available days off and the number of operators needed. The master run list is shown below.

MASTER RUN LIST

Weekday Runs		Saturday Runs		Sunday Runs	
Run #	Pay hours	Run #	Pay hours	Run #	Pay hours
01	8:04	601	8:00	701	8:00
02	8:00	602	8:00	702	8:00
03	8:00	603	8:00	703	8:00
04	8:00	604	8:30	704	8:30
05	8:00	605	9:51	705	9:51
06	8:00				
07	10:17				
08	9:24				

The total number of operators is determined using the formula for computing operators and days off, as shown below. The addition of weekend service on Route 97 results in a total of 10 operators needed for this example, compared to eight for weekday-only service. When Saturday and Sunday runs are part of the cafeteria rostering process, drivers also need to pick their days off. Since only five operators are needed for Saturday and Sunday service, and 10 operators are needed in total, there will be five operators “off” on Saturdays and Sundays. Eight operators are required each weekday, so two of the 10 operators can choose to be off on each weekday.

The table on the following page summarizes the expected rostering outcomes. This goes back to the approach we have discussed in previous sections—that is, to know the outcome before you work through the details and develop a solution.

OPERATORS REQUIRED FOR 8-HOUR RUNS WITH WEEKEND SERVICE

Day	# daily runs	# days per week	Weekly total (daily runs * days)
Weekdays (M-F)	8	5	40
Saturdays	5	1	5
Sundays	5	1	5
Weekly Total			50
Total Operators (weekly total runs / 5 days of work per operator)			10

DISTRIBUTION OF DAYS OFF

	Total # available operators	# daily runs	Operators off each day (# operators - # daily runs)
Weekdays (M-F)	10	8	2
Saturdays	10	5	5
Sundays	10	5	5
Weekly Total (weekdays * 5 + Saturday + Sunday)			20

What might the cafeteria roster look like for this example? Senior operators often prefer to maximize their pay hours and to have weekends free. The nature of the run (straight vs. split) and run begin and end times are also factors considered by operators.

Assume that the first two operators maximize their work hours and pick Saturday and Sunday as their days off, the next two are willing to work one weekend day, and the next two are willing to work both weekend days. The cafeteria roster after these six operators pick their work would look like the example on the following page.

CAFETERIA ROSTER - Route 97 (7 days)

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Platform Hours	Work Hours	Make-up Time	Overtime	Spread Time
1001	Off	107	107	107	107	107	Off					
		10:17	10:17	10:17	10:17	10:17		38:55:00	43:05:00	0:00	3:05:00	13:40
1002	Off	108	108	108	108	108	Off					
		9:24	9:24	9:24	9:24	9:24		35:30:00	39:40:00	0:20	0:00:00	14:00
1003	Off	Off	101	101	101	101	605					
			8:04	8:04	8:04	8:04	9:51	38:16:00	41:26:00	0:00	1:26:00	0:00
1004	705	105	105	105	105	Off	Off					
	9:51	8:00	8:00	8:00	8:00			33:16:00	36:30:00	4:44	1:14:00	0:00
1005	704	101	Off	Off	102	102	604					
	8:30	8:04			8:00	8:00	8:30	36:31:00	39:31:00	1:12	0:43:00	0:00
1006	Off	103	103	103	103	103	Off					
		8:00	8:00	8:00	8:00	8:00		34:05:00	37:25:00	2:35	0:00:00	0:00

Remaining days off available would be:

DAYS OFF ALLOWED Updated

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	1	1	1	2	1	1

The completed cafeteria roster (shown below) has a weekly total of 423:32 hours. This is approximately 84 hours more than the roster for weekday-only service, reflecting the additional 42 hours of work on Saturday and Sunday. Most of this time (393:24 work hours plus 13:04 make-up time) will be paid as straight time. Overtime accounts for 6:28 hours and spread for 27:40. This assumes that make-up and overtime is calculated on a daily basis.

With overtime and spread paid at time and a half and make-up time paid at the straight rate, the actual pay hours will be:

Pay hours including make-up time, overtime, and spread penalty =
393:24 + 13:04 + (6:28x0.5) + (27:40x0.5) = 423:32

CAFETERIA ROSTER - Route 97 (7 days)

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Platform Hours	Work Hours	Make-up Time	Overtime	Spread Time	Weekly Pay Hours
1001	Off	107	107	107	107	107	Off						
		10:17	10:17	10:17	10:17	10:17		38:55:00	43:05:00	0:00	3:05:00	13:40	51:27:30
1002	Off	108	108	108	108	108	Off						
		9:24	9:24	9:24	9:24	9:24		35:30:00	39:40:00	0:20	0:00:00	14:00	47:00:00
1003	Off	Off	101	101	101	101	605						
			8:04	8:04	8:04	8:04	9:51	38:16:00	41:26:00	0:00	1:26:00	0:00	42:09:00
1004	705	105	105	105	105	Off	Off						
	9:51	8:00	8:00	8:00	8:00			33:16:00	36:30:00	4:44	1:14:00	0:00	41:51:00
1005	704	101	Off	Off	102	102	604						
	8:30	8:04			8:00	8:00	8:30	36:31:00	39:31:00	1:12	0:43:00	0:00	41:04:30
1006	Off	103	103	103	103	103	Off						
		8:00	8:00	8:00	8:00	8:00		34:05:00	37:25:00	2:35	0:00:00	0:00	40:00:00
1007	Off	104	104	104	104	104	Off						
		8:00	8:00	8:00	8:00	8:00		35:50:00	39:10:00	0:50	0:00:00	0:00	40:00:00
1008	701	106	106	106	Off	Off	601						
	8:00	8:00	8:00	8:00			8:00	36:30:00	39:30:00	0:30	0:00:00	0:00	40:00:00
1009	702	Off	Off	102	106	106	602						
	8:00			8:00	8:00	8:00	8:00	36:04:00	39:04:00	0:56	0:00:00	0:00	40:00:00
1010	703	102	102	Off	Off	105	603						
	8:00	8:00	8:00			8:00	8:00	34:36:00	38:03:00	1:57	0:00:00	0:00	40:00:00
							TOTAL	359:33:00	393:24:00	13:04:00	6:28:00	27:40:00	423:32:00

It may be useful at this point to walk through an example of the calculations for a specific roster number. In Roster 1001, the daily platform hours for Run 107, taken from the Run Guide at the beginning of this section, are multiplied by 5 to convert to weekly hours: 7:47 x 5 = 38:55.

Total hours are calculated by multiplying the daily total hours from the Run Guide for Run 107 by 5: 8:37 x 5 = 43:05.

Make-up time is calculated in the same way, but Roster 1001 does not include any make-up time.

Overtime was shown in the Run Guide as overtime pay hours (equal to one-half the overtime hours worked); the roster shows actual weekly overtime worked for clarity. Roster 1001 included 37 minutes of daily overtime, which equals 3:05 weekly overtime.

Spread time was also shown in the Run Guide as spread penalty (equal to one-half of actual spread hours); the roster shows actual weekly spread time for clarity. Run 107 included 2:44 of daily spread time, which equals 13:40 weekly spread time.

Tip Some operators calculate overtime on a weekly basis, while others calculate it on a daily basis, paying overtime for all hours over eight in a given day. To calculate the cost of your service, you will need to understand the policies that apply to your system. Calculating pay hours for a system that pays overtime daily requires making a calculation for each day of the week, and multiplying that day times the number of days that condition occurs in the year.

Tip When calculating annual costs BE CAREFUL—holidays that occur during the week often use weekend or special schedules. Do not assume that "Monday" service occurs on every Monday during a calendar year.

Tip Combining daily runs with significant overtime with daily runs under eight hours can increase efficiency when overtime and guarantees are calculated weekly.

The formula for weekly pay hours is:

		Work hours	+	*Make-up time*	+	*(Overtime x 0.5)*	+	*(Spread time x 0.5)*	=	*Weekly pay hours*
Weekly pay hours For Roster 1001	**=**	**43:05**	**+**	**0**	**+**	**(3:05 x 0.5)**	**+**	**(13:40 x 0.5)**	**=**	**51:27:30**

The pay-to-platform ratio is one of the most useful means of evaluating rosters. In this example, the pay-to-platform ratio is:

Pay to platform = 423:32 / 359:33 = 1.178

Agency-developed Rostering—Weekday and Weekend Service

With agency-developed rostering, the agency "pre-packages" the runs into weekly rosters. The operators then pick from the agency-developed list of weekly rosters.

A number of factors influence how packages (Lines of Work) are developed for the weekly rosters. In cases where overtime and make-up time are calculated on a weekly and not daily basis, there is the opportunity to combine daily runs with greater than eight hours pay time with daily runs paying less than eight hours to reduce or eliminate weekly overtime and make-up time. In the basic rostering section, the agency-developed roster reduced the pay-to-platform ratio from 1.258 for the cafeteria roster to 1.225.

As shown earlier on the Master Run list, there are two long runs on weekdays and two on weekends. Several weekday runs (notably runs 102, 103, and 105) require at least 30 minutes of make-up time daily. The objective of developing weekly rosters is to combine these runs into weekly work assignments that minimize overtime and make-up time. Ideally, work assignments will be as close to 40 hours per week as possible.

A common approach to developing agency rosters is to adjust assignments with the most overtime or make-up time first, and then address remaining assignments. Rosters 1001 and 103 have the most weekly overtime, while Rosters 1004, 1006, 1010, and 1005 have the most make-up time. In the example on the following page, switches in assignments are highlighted in bold.

The first switch is between Rosters 1001 and 1006: the Wednesday through Friday runs have been exchanged to reduce overtime on Roster 1001 and make-up time on Roster 1006. Next, the Saturday runs have been switched between Rosters 1003 and 1008. The Tuesday runs on Rosters 1003 and 1004 have been exchanged. Finally, Run 107 on Thursday, which had been switched from Roster 1001 to Roster 1006, has been exchanged again with Run 105 from Roster 1004.

What is the end result of this agency-developed roster? See below—weekly overtime has been eliminated, and weekly make-up time has been reduced from 13:04 to 7:32. Pay hours are now calculated as:

Pay hours including make-up time, overtime, and spread penalty =
392:28 + 7:32 + (0:00x0.5) + (27:40x0.5) = 413:50
Pay to platform = 413:50 / 359:33
= 1.151

AGENCY-DEVELOPED ROSTER - Route 97 (7 days)

Roster No.	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Platform Hours	Straight Time	Make-up Time	Overtime	Spread Time	Weekly Pay Hours
1001	Off	07	07	**03**	**03**	**03**	Off						
		10:17	10:17	**8:00**	**8:00**	**8:00**		36:01:00	39:41:00	0:19	0:00:00	5:28	42:44:00
1002	Off	08	08	08	08	08	Off						
		9:24	9:24	9:24	9:24	9:24		35:30:00	39:40:00	0:20	0:00:00	14:00	47:00:00
1003	Off	Off	**05**	01	01	01	**603**						
			8:00	8:04	8:04	8:04	**8:00**	35:47:00	38:58:00	1:02	0:00:00	0:00	40:00:00
1004	705	05	**01**	05	**07**	Off	Off						
	9:51	8:00	**8:04**	8:00	**10:17**			36:10:00	39:02:00	0:58	0:00:00	2:44	41:22:00
1005	704	01	Off	Off	02	02	604						
	8:30	8:04			8:00	8:00	8:30	36:31:00	39:31:00	0:29	0:00:00	0:00	40:00:00
1006	Off	03	03	**07**	**05**	**07**	Off						
		8:00	8:00	**10:17**	**8:00**	**10:17**		35:20:00	39:01:00	0:59	0:00:00	5:28	42:44:00
1007	Off	04	04	04	04	04	Off						
		8:00	8:00	8:00	8:00	8:00		35:50:00	39:10:00	0:50	0:00:00	0:00	40:00:00
1008	701	06	06	06	Off	Off	**601**						
	8:00	8:00	8:00	8:00			**8:00**	36:30:00	39:30:00	0:30	0:00:00	0:00	40:00:00
1009	702	Off	Off	02	06	06	602						
	8:00			8:00	8:00	8:00	8:00	36:04:00	39:04:00	0:56	0:00:00	0:00	40:00:00
1010	703	02	02	Off	Off	05	605						
	8:00	8:00	8:00			8:00	9:51	35:50:00	38:51:00	1:09	0:00:00	0:00	40:00:00
					TOTAL WEEKLY HOURS			359:33:00	392:28:00	7:32:00	0:00:00	27:40:00	413:50:00

Weekly pay hours have been reduced from 423:32 to 413:50. The agency-developed roster has reduced the pay-to-platform ratio from 1.178 to 1.151. Typically, agency-developed rosters are more efficient because of the ability to package long and short runs in a weekly roster. The reduction in pay-to-platform ratio was slight in this example only because the original roster was very efficient.

Another key benefit is the ability to package a greater proportion of attractive Lines of Work. The outcome can be that the less senior employees are not just operating the undesirable runs or workweeks, and have an overall better working life. This has the potential to translate into lower staff turnover among the less senior employees, which is an issue for many transit systems.

One other consideration is that early and late runs should generally not be mixed in a given roster. The reasons for this are both fatigue-related (obvious if moving from a late finish to an early start), and also because, as a general rule, operators prefer low variance in the start and/or end times of their working days. The agency may have rules governing time off between shifts, but even without such rules it is not a good idea to have an operator pull in late in the evening and pull out early the following morning. A roster with early runs and a late run on the last work day would be acceptable under time-off rules, but operators generally do not find this desirable.

A comparison of the cafeteria and agency rostering results is shown below.

COMPARISON CHART FOR CAFETERIA VS. AGENCY ROSTERING

	Cafeteria	Agency
Total hours for all weekly rosters	423:32:00	423:32:00
@ Straight time without make-up	393:24:00	392:28:00
@ Make-up hours	13:04:00	7:32:00
@ Overtime hours	6:28:00	0:00:00
@ Spread hours	27:40:00	27:40:00
Pay hours	423:32:00	413:50:00
Number of operators required	10	10
Total platform hours	359:33:00	359:33:00
Pay-to-platform ratio	1.178	1.151

Day Off Patterns

Quality of working weeks is also an important consideration when developing rosters. This applies particularly to how day off patterns are developed and rest times are ensured (above minimum requirements). The scheduler should be able to predict the day off patterns before developing the rosters. For any fixed set of input runs (i.e., the weekday, Saturday & Sunday runs to be rostered) there will be an 'optimum' set of day off patterns. Some of the considerations of day off patterns will include:

- Whether days off must be consecutive (particularly applies to four-day workweeks where two consecutive plus one other day may be acceptable)
- Which combinations of days are preferred. For example, is a Thursday/Friday combination preferable to a Friday/Saturday combination (probably not)?
- Whether having an entire weekend off is an important consideration. If so more Thursday/Friday and Monday/Tuesday combinations will be preferred over Friday/Saturday and Sunday/Monday combinations, which will in turn allow more Saturday/Sunday weekend day off combinations to be created. The following graphics illustrate day off patterns for two options. Option 1 requires consecutive days off. Option 2 allows this to be traded off against additional full weekends off. The patterns that result are shown below:

Combination	Option 1	Option 2
Saturday/Sunday	4	5
Sunday/Monday	1	
Monday/Tuesday	1	2
Tuesday/Wednesday	1	
Wednesday/Thursday	1	1
Thursday/Friday	1	1
Friday/Saturday	1	
Wednesday/Friday (Split Days)		1

As the table shows, revising day off combinations can achieve an additional entire weekend off (increases from four to five) with the same set of input runs. However, this outcome requires a split days off combination, which may or may not be permissible under your labor rules. If split days off are not allowed, this would not be a valid option; however the example is provided to illustrate the concept of alternative approaches to days off patterns.

Days off can be easily displayed as a basic roster, without the daily hours or numbers. This allows a more simple visualization of the roster pattern. In developing a roster it may be best to develop this blank pattern first, and then simply “fill in the blanks” to complete the roster.

Days Off Pattern - Option 1

Roster	Sun	Mon	Tue	Wed	Thur	Fri	Sat
1	Off						Off
2	Off						Off
3	Off						Off
4	Off						Off
5	Off	Off					
6						Off	Off
7		Off	Off				
8					Off	Off	
9				Off	Off		
10			Off	Off			

Days Off Pattern - Option 2

Roster	Sun	Mon	Tue	Wed	Thur	Fri	Sat
1	Off						Off
2	Off						Off
3	Off						Off
4	Off						Off
5	Off						Off
6		Off	Off				
7		Off	Off				
8					Off	Off	
9				Off	Off		
10				Off		Off	

Agency-developed Rosters with Part-time Operators

Part-time operators are allowed at many transit agencies, often with restrictions on the maximum number of hours allowed per week or the number or percentage of part-timers. The examples in this section did not involve part-time operators because the runcut did not produce any runs shorter than 6:49. If your runcut results in runs of six hours or less, these can be combined into a weekly part-time roster (30 hours per week is a typical upper limit for part-time operators). Alternately, short and long runs might be mixed as in the preceding example to produce a more efficient roster.

The naming of which runs are part time and which are full time can be reconsidered as part of the rostering process, again depending upon what the labor agreement allows. This is discussed in greater detail in the advanced section.

Agency-developed Four-day and Five-day Rosters

The development of four-day rosters is a viable option for many agencies. The ability to convert overtime to straight time is a primary advantage of four-day rosters (especially if overtime is paid on a daily basis), and is usually present if there are runs close to 10 hours in length. The example in this section includes one weekday run longer than 10:00, another weekday run 9:24 in length, and a Saturday and Sunday run 9:51 in length. Since each weekday run is operated five days a week, these 12 runs could have formed three four-day rosters. The remaining 38 runs could then form seven five-day rosters and one part-time roster consisting of three days' work. However, the ability to mix and match runs in rosters would be limited if the longer runs are reserved for four-day rosters.

A significant portion of any cost savings from the use of four-day rosters may be offset by the added cost of hiring and training additional operators and paying additional fringe benefits. The iterative nature of runcutting and rostering may result in a different runcut that would be conducive to four-day rosters without increasing the need for added operators. For many operators, a four-day roster is a welcome option because it provides an additional day off during the week.

In short the number of operators required to operate four 10-hour runs over a workweek is usually the same as required to operate five eight-hour runs. While the 10-hour runs result in fewer runs at the runcut stage, the additional days off required for the four-day workweek result in the same number of total operators. In simple terms the 25% saving in runs (eight hours to 10 hours) is offset by the equivalent additional days off required (25% or one in four) by four-day workweeks.

LEVEL 2

End of Intermediate Rostering.

The Advanced Section of Rostering continues on the next page.

To jump to Rail Scheduling, go to page 7-1.

6.3 Advanced Rostering

LEVEL 3

The advanced section in Chapter 5: Runcutting did not develop any significantly different runcuts. Previous sections of this chapter have addressed the principal issues and approaches in rostering.

Agencies that use cafeteria rostering have no control over the final rosters, other than ensuring that they are in accord with all applicable rules and regulations. The operators put together their own rosters by selecting runs and days off from the master lists.

Agencies that develop their own rosters may find several opportunities to minimize costs:

- If make-up time and/or overtime are calculated on a weekly (40 hours per week) rather than a daily (eight hours per day) basis, the scheduler can combine short and long runs in a given roster to avoid make-up time and overtime. As seen in the intermediate section, this strategy can reduce weekly pay hours and improve the pay-to-platform ratio.
- If make-up time and overtime are calculated on a daily basis, then mixing and matching will not achieve any savings. The tools available to a scheduler in these circumstances include whether and how much to utilize 4/10 rosters and how to roster tripper runs.
- 4/10 runs may generate savings by reducing the number of daily runs and the associated travel, sign-in, and clear times. As noted in the advanced runcutting section, 4/10 rosters will not reduce the number of operators needed, since the total number of operators required is a function of how much work is undertaken in a week, not in a given runcut. If there are many long runs around 10 hours in length and if your agency allows four-day workweeks with 10-hour days, the scheduler should experiment with different levels of 4/10 rosters to assess the impacts.
- Some agencies even develop rosters with five 10-hour daily runs as a method of reducing the number of required operators. However, as expected, this rostering practice results in a high level of weekly overtime. See the discussion of overtime optimization in the advanced section of Chapter 5:Runcutting for a more in-depth discussion of potential benefits and pitfalls of high levels of overtime.
- **Tripper** runs may be packaged into part-time rosters if an agency uses part-time operators. Alternately, agencies may choose not to assign these runs in a roster, but instead to leave them open to be operated by the extraboard. The runcut develops tripper runs, but these are not assigned an "operator type" until the rostering stage. The scheduler should be aware of the rostering and bidding impacts of the runs, and the rules that apply to part-time operators in selecting the runs that have been created.

tripper

A short piece of work whose total time is less than that specified as constituting a full-time run. A tripper is often a piece of work in the AM or PM peak period that cannot be combined with another piece of work to form a split run because of insufficient hours, excessive swing time, or excessive spread time. Trippers are often operated by extraboard or part-time operators. Tripper can also refer to a vehicle that pulls out, makes no more than one round-trip, and pulls in.

In some cases, the labor agreement may specify that a single roster can consist only of runs on the same route, or the same run type, or the same equipment type. Meeting these requirements often results in separately identified rosters for picking, e.g., regular and relief. Rules like these can also affect cafeteria rosters. For example, a modified cafeteria roster may require an operator to pick the same run on each weekday that it is available.

The "quality" of agency-developed rosters is an important consideration. Rosters dictate the operator's work life. When mixing and matching runs, care should be taken to combine AM runs only or PM runs only in a single roster. Operators also prefer an earlier end time on the day preceding a day off, although this cannot be managed for all rosters. Attention to operator preferences when developing rosters can improve morale, often with no impact on costs or efficiency.

Advanced Topics in Rostering

Revisiting Run Types

Thus far we have kept run types as per the runcut—full time into a full-time roster, part time kept separate (or even packaged into part-time Lines of Work), and even kept 5/8 and 4/10 rosters separate. However the rostering process has the capacity to revisit even basic assumptions about what a part-time run or full-time run is.

Often a full-time or part-time run is determined not by daily hours but by weekly hours (this is not always the case, e.g., when the daily runs that can be assigned to an operator type are specified). Therefore it is not the 8-hour day but the 40-hour week that designates a full-time run.

A part-time run, in some circumstances, may therefore be made up of three 10-hour runs, or four 7.5-hour runs. These runs would normally be assumed as full time and at the runcut stage would have been created and designated as such.

What would the benefits of such an approach be? One would be better and more reliable work hours/days for part-time employees. Consider a part-time employee that covered two weekend 10-hour runs and one additional weekday run. That would leave four days free to study, seek other employment, or for whatever lifestyle choice is preferred (often the reason for seeking a part-time job in the first place).

In this example one weekday run, one Saturday run, and one Sunday run have been covered by two employees, and with no overtime or guarantee costs (assuming weekly overtime and packaged Lines of Work). In addition, the potentially lower pay rates and benefits for part-time staff mean that in many cases maximum utilization of part-timers is efficient—the issue often is that the types of work weeks offered to part-time staff are not attractive, often being small peak pieces of work, or two small peak pieces of work separated by a long break.

The aim of this section is not to attempt a prescriptive solution, as the "optimal" outcome will depend on a range of specific labor rules and conditions. Some of these will include:

- Daily and weekly hour limitations
- Pay rates and benefits for full-time and part-time staff
- Peak-to-base ratio, which may mandate a significant number of shorter peak runs
- Employee preferences
- The amount of weekend service operated
- Preferences for 4/10 or 5/8 work weeks of full-time staff
- Capacity to attract and retain part-time staff

The intent here is to note the possibility to think beyond traditional scheduling approaches when rostering, and to reconsider how part-time and full-time staff are applied, and how run types can be redefined.

Rotary Rostering

The concept of a Rotating Roster was mentioned previously. In this type of roster, the operators "rotate" or move from one Line of Work to the next. The concept is relatively simple in that an operator moves from one workweek to the next, throughout the sign-up period. This is depicted in the example below, based upon our Line 97 roster from the previous section.

Operator	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
1	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010
2	1002	1003	1004	1005	1006	1007	1008	1009	1010	1001
3	1003	1004	1005	1006	1007	1008	1009	1010	1001	1002
4	1004	1005	1006	1007	1008	1009	1010	1001	1002	1003
5	1005	1006	1007	1008	1009	1010	1001	1002	1003	1004
6	1006	1007	1008	1009	1010	1001	1002	1003	1004	1005
7	1007	1008	1009	1010	1001	1002	1003	1004	1005	1006
8	1008	1009	1010	1001	1002	1003	1004	1005	1006	1007
9	1009	1010	1001	1002	1003	1004	1005	1006	1007	1008
10	1010	1001	1002	1003	1004	1005	1006	1007	1008	1009

ROTATION - OPERATOR 5

Week	Roster	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	**1005**	704 8:30	01 8:04	Off	Off	02 8:00	02 8:00	604 8:30
2	**1006**	Off	03 8:00	03 8:00	07 10:17	05 8:00	07 10:17	Off
3	**1007**	Off	04 8:00	04 8:00	04 8:00	04 8:00	04 8:00	Off
4	**1008**	701 8:00	06 8:00	06 8:00	06 8:00	Off	Off	601 8:00
5	**1009**	702 8:00	Off	Off	02 8:00	06 8:00	06 8:00	602 8:00
6	**1010**	703 8:00	02 8:00	02 8:00	Off	Off	05 8:00	605 9:51
7	**1001**	Off	07 10:17	07 10:17	03 8:00	03 8:00	03 8:00	Off
8	**1002**	Off	08 9:24	08 9:24	08 9:24	08 9:24	08 9:24	Off
9	**1003**	Off	Off	05 8:00	01 8:04	01 8:04	01 8:04	603 8:00
10	**1004**	705 9:51	05 8:00	01 8:04	05 8:00	07 10:17	Off	Off

Some complexity can appear when moving from one workweek to the next. In the example above the operator moves from Roster Line 1005 to 1006. However, that results in only one day off between Thursday in week one and Friday in week two—this may not meet labor agreement requirements.

The consequence is that the roster needs to be built with regard to meeting requirements for the entire rotating period—so that changes as operators move through the different packages from week to week fall within labor agreement requirements. This can significantly complicate the rostering process.

The outcome of this approach, used predominantly outside North America, is that the workweeks are shared equally by the operators over the roster period. In order to mitigate significant lifestyle changes from week to week (e.g., moving from split runs one week to AM runs the next week to PM runs the following week) it may be that several distinct rosters are created (e.g., a "Split runs" roster, an "AM Runs" roster, a "PM Runs" roster, etc.), and operators rotate within those distinct rosters.

Rostering for Longer Periods

While the base rostering concept typically covers a repeating workweek there are situations where rosters are built for longer periods. Typically this will be either four or 12 weeks, but may vary. For longer periods the process and issue are very much the same as for the weekly roster.

However, the Rotating Roster concept above noted the issue of meeting labor agreement requirements over more than one week. This can apply to a range of labor agreement rules.

The kinds of considerations that need to be monitored include:

- Days off requirements over 1 week and multiple weeks
- Rest times, particularly when moving from one week to the next
- Total work hours over one week and the entire period (which may also be limited by driving time regulations)

Rostering for longer periods adds additional levels of complexity to the rostering process.

Below is an example of what part of the roster may look like in our Line 97 example. Note the similar workweeks to the weekly roster, but days off patterns are adjusted to ensure legality.

4-Week Roster

Roster	Week	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1001	1	704 8:30	101 8:04	Off	Off	102 8:00	102 8:00	604 8:30
	2	Off	Off	105 8:00	101 8:04	101 8:04	101 8:04	603 8:00
	3	Off	103 8:00	103 8:00	107 10:17	105 8:00	107 10:17	Off
	4	Off	104 8:00	104 8:00	104 8:00	104 8:00	104 8:00	Off
1002	1	701 8:00	106 8:00	106 8:00	106 8:00	Off	Off	601 8:00
	2	702 8:00	Off	Off	102 8:00	106 8:00	106 8:00	602 8:00
	3	703 8:00	102 8:00	102 8:00	Off	Off	105 8:00	605 9:51
	4	Off	107 10:17	107 10:17	103 8:00	103 8:00	103 8:00	Off

A More Automated Spreadsheet

We have discussed in previous chapters the need to utilize automated spreadsheet functionality to enhance spreadsheet-based scheduling. This applies strongly to rostering under either the cafeteria- or scheduler-developed approaches.

We will reiterate a few key points:

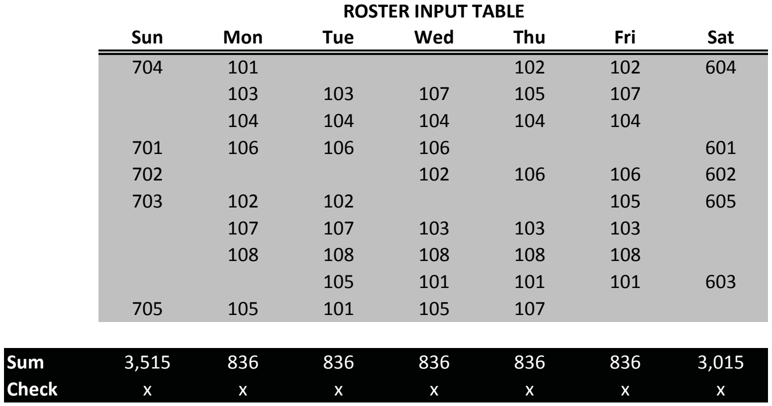
- Limit the amount of typed data to those things that must be typed. Anything that can be a formula, should be a formula—without exception . This will reduce errors, minimize data input time, and significantly enhance the process. Typed values in a spreadsheet are one of the greatest sources of errors in the spreadsheet-based scheduling process and are often unnecessary, i.e., they could have been calculated values.
- Use error trapping techniques. Simple checks can be developed to automatically iden-

tify errors or alert the scheduler to issues.

- Use formatting to enhance the output and "viewability." Spreadsheets can be formatted to produce elegant reports for distribution, or to assist the scheduler in viewing solutions.
- Use conditional formatting to further enhance the presentation, for error identification, or to highlight certain outcomes.

Let's look again at the basic 10-operator roster developed in the previous section. But this time we will only allow typed input into two areas—the daily runs and the basic roster information (which runs form a roster). These areas are shaded in dark gray below.

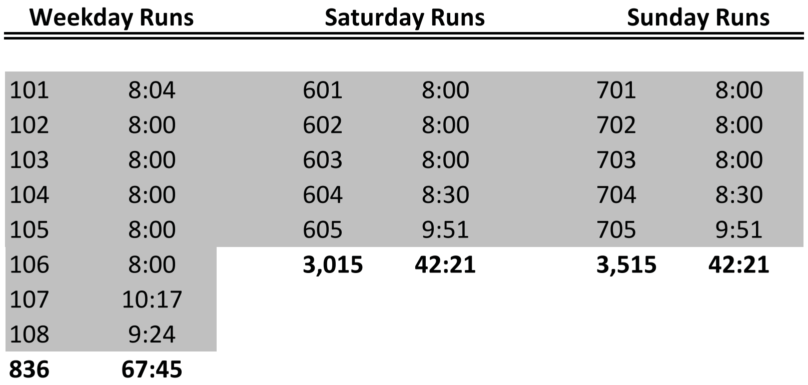
ROSTER INPUT TABLE



ROSTER INPUT TABLE

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
	704	101			102	102	604
		103	103	107	105	107	
		104	104	104	104	104	
	701	106	106	106			601
	702			102	106	106	602
	703	102	102			105	605
		107	107	103	103	103	
		108	108	108	108	108	
			105	101	101	101	603
	705	105	101	105	107		
Sum	3,515	836	836	836	836	836	3,015
Check	x	x	x	x	x	x	x

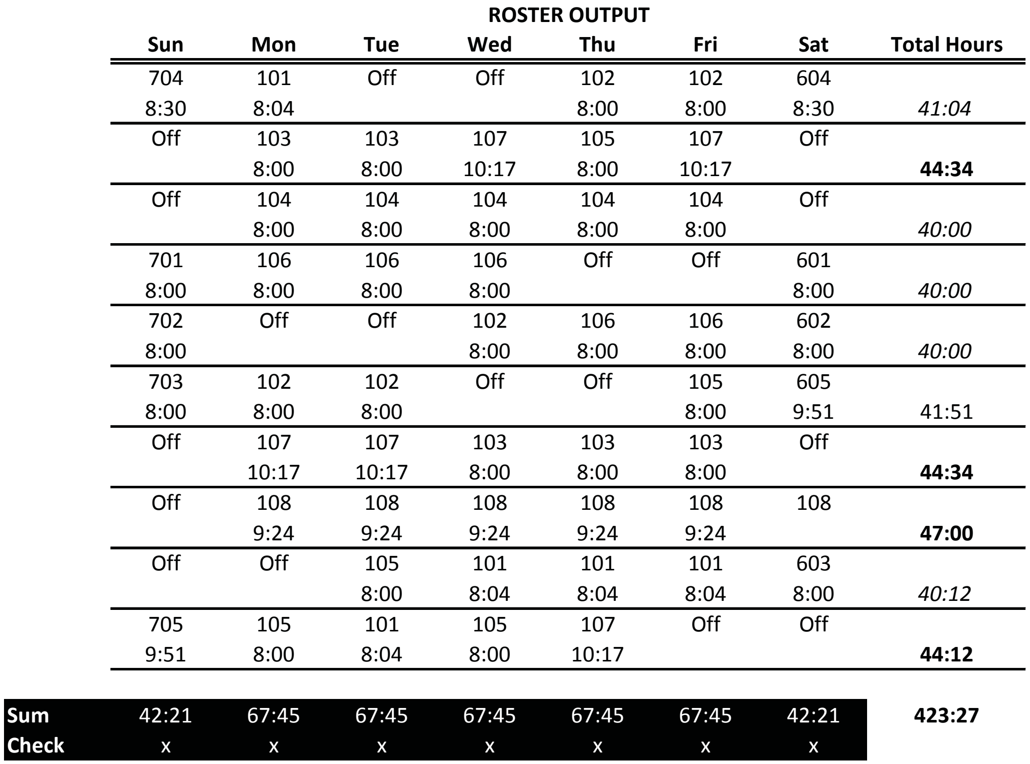
RUNS TO BE ROSTERED



Weekday Runs		**Saturday Runs**		**Sunday Runs**	
101	8:04	601	8:00	701	8:00
102	8:00	602	8:00	702	8:00
103	8:00	603	8:00	703	8:00
104	8:00	604	8:30	704	8:30
105	8:00	605	9:51	705	9:51
106	8:00	**3,015**	**42:21**	**3,515**	**42:21**
107	10:17				
108	9:24				
836	**67:45**				

These basic inputs are then used to generate the roster output, which looks very much like that presented in the previous section but without the totals (for simplicity sake, since the totals are easily calculated by basic formulas anyway).

ROSTER OUTPUT

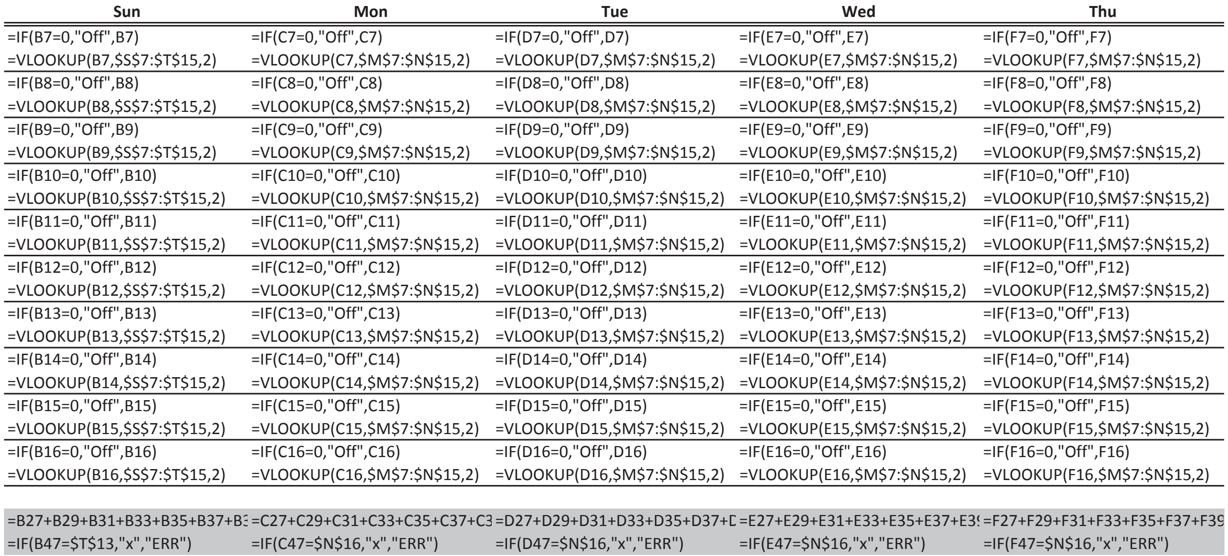


ROSTER OUTPUT

	Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Total Hours**
	704 8:30	101 8:04	Off	Off	102 8:00	102 8:00	604 8:30	*41:04*
	Off	103 8:00	103 8:00	107 10:17	105 8:00	107 10:17	Off	**44:34**
	Off	104 8:00	104 8:00	104 8:00	104 8:00	104 8:00	Off	*40:00*
	701 8:00	106 8:00	106 8:00	106 8:00	Off	Off	601 8:00	*40:00*
	702 8:00	Off	Off	102 8:00	106 8:00	106 8:00	602 8:00	*40:00*
	703 8:00	102 8:00	102 8:00	Off	Off	105 8:00	605 9:51	41:51
	Off	107 10:17	107 10:17	103 8:00	103 8:00	103 8:00	Off	**44:34**
	Off	108 9:24	108 9:24	108 9:24	108 9:24	108 9:24	108	**47:00**
	Off	Off	105 8:00	101 8:04	101 8:04	101 8:04	603 8:00	*40:12*
	705 9:51	105 8:00	101 8:04	105 8:00	107 10:17	Off	Off	**44:12**
Sum	42:21	67:45	67:45	67:45	67:45	67:45	42:21	**423:27**
Check	x	x	x	x	x	x	x	

Every cell in the above table is calculated through the use of lookup functions. The only typed value then becomes the daily inputs above, which can be manipulated and adjusted, and the results are seen immediately.

Formulas are shown below. Only a subset of the output table is shown for readability purposes.



Sun	Mon	Tue	Wed	Thu
=IF(B7=0,"Off",B7) =VLOOKUP(B7,$S$7:$T$15,2)	=IF(C7=0,"Off",C7) =VLOOKUP(C7,$M$7:$N$15,2)	=IF(D7=0,"Off",D7) =VLOOKUP(D7,$M$7:$N$15,2)	=IF(E7=0,"Off",E7) =VLOOKUP(E7,$M$7:$N$15,2)	=IF(F7=0,"Off",F7) =VLOOKUP(F7,$M$7:$N$15,2)
=IF(B8=0,"Off",B8) =VLOOKUP(B8,$S$7:$T$15,2)	=IF(C8=0,"Off",C8) =VLOOKUP(C8,$M$7:$N$15,2)	=IF(D8=0,"Off",D8) =VLOOKUP(D8,$M$7:$N$15,2)	=IF(E8=0,"Off",E8) =VLOOKUP(E8,$M$7:$N$15,2)	=IF(F8=0,"Off",F8) =VLOOKUP(F8,$M$7:$N$15,2)
=IF(B9=0,"Off",B9) =VLOOKUP(B9,$S$7:$T$15,2)	=IF(C9=0,"Off",C9) =VLOOKUP(C9,$M$7:$N$15,2)	=IF(D9=0,"Off",D9) =VLOOKUP(D9,$M$7:$N$15,2)	=IF(E9=0,"Off",E9) =VLOOKUP(E9,$M$7:$N$15,2)	=IF(F9=0,"Off",F9) =VLOOKUP(F9,$M$7:$N$15,2)
=IF(B10=0,"Off",B10) =VLOOKUP(B10,$S$7:$T$15,2)	=IF(C10=0,"Off",C10) =VLOOKUP(C10,$M$7:$N$15,2)	=IF(D10=0,"Off",D10) =VLOOKUP(D10,$M$7:$N$15,2)	=IF(E10=0,"Off",E10) =VLOOKUP(E10,$M$7:$N$15,2)	=IF(F10=0,"Off",F10) =VLOOKUP(F10,$M$7:$N$15,2)
=IF(B11=0,"Off",B11) =VLOOKUP(B11,$S$7:$T$15,2)	=IF(C11=0,"Off",C11) =VLOOKUP(C11,$M$7:$N$15,2)	=IF(D11=0,"Off",D11) =VLOOKUP(D11,$M$7:$N$15,2)	=IF(E11=0,"Off",E11) =VLOOKUP(E11,$M$7:$N$15,2)	=IF(F11=0,"Off",F11) =VLOOKUP(F11,$M$7:$N$15,2)
=IF(B12=0,"Off",B12) =VLOOKUP(B12,$S$7:$T$15,2)	=IF(C12=0,"Off",C12) =VLOOKUP(C12,$M$7:$N$15,2)	=IF(D12=0,"Off",D12) =VLOOKUP(D12,$M$7:$N$15,2)	=IF(E12=0,"Off",E12) =VLOOKUP(E12,$M$7:$N$15,2)	=IF(F12=0,"Off",F12) =VLOOKUP(F12,$M$7:$N$15,2)
=IF(B13=0,"Off",B13) =VLOOKUP(B13,$S$7:$T$15,2)	=IF(C13=0,"Off",C13) =VLOOKUP(C13,$M$7:$N$15,2)	=IF(D13=0,"Off",D13) =VLOOKUP(D13,$M$7:$N$15,2)	=IF(E13=0,"Off",E13) =VLOOKUP(E13,$M$7:$N$15,2)	=IF(F13=0,"Off",F13) =VLOOKUP(F13,$M$7:$N$15,2)
=IF(B14=0,"Off",B14) =VLOOKUP(B14,$S$7:$T$15,2)	=IF(C14=0,"Off",C14) =VLOOKUP(C14,$M$7:$N$15,2)	=IF(D14=0,"Off",D14) =VLOOKUP(D14,$M$7:$N$15,2)	=IF(E14=0,"Off",E14) =VLOOKUP(E14,$M$7:$N$15,2)	=IF(F14=0,"Off",F14) =VLOOKUP(F14,$M$7:$N$15,2)
=IF(B15=0,"Off",B15) =VLOOKUP(B15,$S$7:$T$15,2)	=IF(C15=0,"Off",C15) =VLOOKUP(C15,$M$7:$N$15,2)	=IF(D15=0,"Off",D15) =VLOOKUP(D15,$M$7:$N$15,2)	=IF(E15=0,"Off",E15) =VLOOKUP(E15,$M$7:$N$15,2)	=IF(F15=0,"Off",F15) =VLOOKUP(F15,$M$7:$N$15,2)
=IF(B16=0,"Off",B16) =VLOOKUP(B16,$S$7:$T$15,2)	=IF(C16=0,"Off",C16) =VLOOKUP(C16,$M$7:$N$15,2)	=IF(D16=0,"Off",D16) =VLOOKUP(D16,$M$7:$N$15,2)	=IF(E16=0,"Off",E16) =VLOOKUP(E16,$M$7:$N$15,2)	=IF(F16=0,"Off",F16) =VLOOKUP(F16,$M$7:$N$15,2)
=B27+B29+B31+B33+B35+B37+B3 =IF(B47=$T$13,"x","ERR")	=C27+C29+C31+C33+C35+C37+C3 =IF(C47=$N$16,"x","ERR")	=D27+D29+D31+D33+D35+D37+D =IF(D47=$N$16,"x","ERR")	=E27+E29+E31+E33+E35+E37+E3 =IF(E47=$N$16,"x","ERR")	=F27+F29+F31+F33+F35+F37+F39 =IF(F47=$N$16,"x","ERR")

A further enhancement to the sheet is the checking and visualization of data through the use of conditional formatting. In the example below the weekly totals are shown according to a preferred range—less than the preferred range in italic, more than the preferred range in bold. Again this is automated, where the cell formatting references the cells with the preferred range.

ROSTER OUTPUT

	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Total Hours
	704	101	Off	Off	102	102	604	
	8:30	7:04			8:00	8:00	8:30	***40:04***
	Off	103	103	107	105	107	Off	
		8:00	8:00	10:17	8:00	10:17		**44:34**
	Off	104	104	104	104	104	Off	
		8:00	8:00	8:00	8:00	8:00		***40:00***
	701	106	106	106	Off	Off	601	
	8:00	8:00	8:00	8:00			8:00	***40:00***
	702	Off	Off	102	106	106	602	
	8:00			8:00	8:00	8:00	8:00	***40:00***
	703	102	102	Off	Off	105	605	
	8:00	8:00	8:00			8:00	9:51	41:51
	Off	107	107	103	103	103	Off	
		10:17	10:17	8:00	8:00	8:00		**44:34**
	Off	108	108	108	108	108	108	
		9:24	9:24	9:24	9:24	9:24		**47:00**
	Off	Off	105	101	101	101	603	
			8:00	8:04	8:04	8:04	8:00	***40:12***
	705	105	101	105	107	Off	Off	
	9:51	8:00	8:04	8:00	10:17			**44:12**
Sum	42:21	66:45	67:45	67:45	67:45	67:45	42:21	**422:27**
Check	x	ERR	x	x	x	x	x	

Preferred Range	
Max	42:00
Min	40:30

Finally the above table shows an error check, based on a simple formula (that checks to be sure the total hours assigned for a day match the total daily run hours). The formula result is highlighted with a conditional format. In the example above, an incorrect time was entered manually for Run 101 on Monday, leading to an error message in the row marked "Check."

This example provides an indication of some basic spreadsheet functionality that can be applied to automate manual processes and reduce the risk of error. Current spreadsheets have significant features, including the ability to write specific code, that enable a range of effective approaches to assist the scheduling process.

Computerized/Automated Rostering

Rostering is another part of the scheduling process to benefit from computerized programs, in many of the typical ways. Rostering constantly involves making trade-offs between efficiency, quality, and operator preferences. Often these preferences counteract each other and so a balance must be found.

In particular, the ability to run numerous iterations with almost instant results (due to the relatively simple math involved) allows the scheduler good control over solutions.

The basic scheduling tenets discussed previously still hold true—you should know what the answer will be before the computer provides it, you must question the outputs, and you should be prepared to run numerous iterations until a final solution is achieved.

Day off patterns may or may not be developed automatically by the computer program. If so, great—but check and test it. If not, work through it yourself. The computer can then "fill in the empty boxes" of the blank pattern, subject to the hard and soft rules defined. Then the solution can be reviewed. And so it goes—refine the rules, run again, review again.

1. **Hard rules.** The types of hard rules will include factors such as:
    - Minimum/maximum work hours in a period
    - Rest break requirements
    - Total days worked in a week or period
    - Day off requirements (must they be consecutive, even for four-day weeks?)
    - Other restrictions around run types, similar start/finish times, or routes operated

2. **Constraints.** As with runcutting there will be a series of constraints, or "soft" rules. These will tend to address the kinds of tradeoffs discussed throughout this section—weekends off versus split days off, start/finish time harmonization versus preferred work times.

3. **Cost Elements.** And of course there will be required costing inputs, including:
    - Labor pay rates
    - Overtime and guarantee requirements
    - Benefits

The rostering function will tend to look very much like a spreadsheet—a pattern with cells for each work day, and each row representing a workweek. Typically the system will allow the scheduler to manually input or swap runs and immediately see the costing (or other impacts).

As with all other aspects of scheduling the computerized software is only a tool at the disposal of the scheduler. In most cases a purely automated solution is unlikely to be the "best" solution, as it is difficult to successfully capture all preferences/approaches in a form that a system can compute at a mathematical level. This is why running a number of iterations and working interactively with the system is necessary.

Rostering Outputs

The examples here have provided some basic outputs. In reality rosters tend to be larger and require additional information to be provided to downstream users. The kinds of reports to be utilized during the rostering should include:

- Statistics, inclusive of costs, manpower requirements, preferably broken down and aggregated as required.
- Outputs that display the roster in a simple format that provides the required information for various users (the scheduler, operations staff, operators, etc.). This could include the run number, start/finish times and worked hours, across the week, for each roster assignment.
- Error checking reports to ensure all runs are assigned, all are legal, etc.

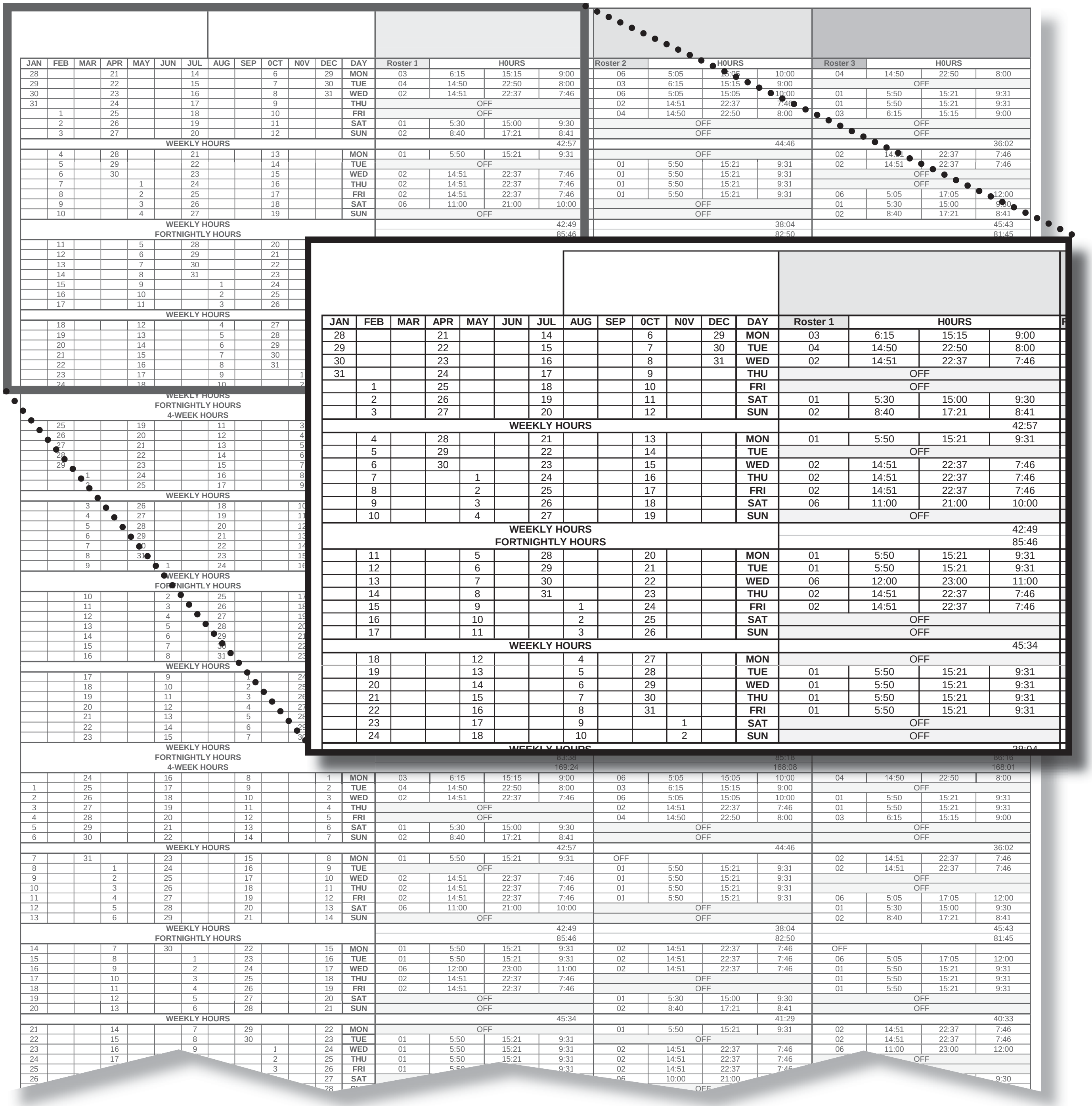
The rostering reports will typically be customized to suit the requirements of a particular agency. One additional sample report is provided on the opposite page. We include it since it provides an indication of the volume of information that can be generated without great difficulty and the amount of time that can be shown. In this case it provides the master roster for three operators for an entire year.

Extraboard Considerations

The topic of the extraboard has been raised but never fully discussed at various points throughout this manual. Extraboard considerations are presented here.

Why mention extraboard in a scheduling manual? Well, because at many transit systems, schedule personnel are responsible for helping to "size" the extraboard and generally to sign up operators to staff it (or to "hold it down").

For those somewhat unfamiliar with the extraboard (generally called spareboard in Canada), it is a group of jobs that is filled at the time of the sign-up with operators who choose to be



JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	0CT	N0V	DEC	DAY	Roster 1	H0URS		
28			21			14			6		29	MON	03	6:15	15:15	9:00
29			22			15			7		30	TUE	04	14:50	22:50	8:00
30			23			16			8		31	WED	02	14:51	22:37	7:46
31			24			17			9			THU	OFF			
	1		25			18			10			FRI	OFF			
	2		26			19			11			SAT	01	5:30	15:00	9:30
	3		27			20			12			SUN	02	8:40	17:21	8:41
WEEKLY HOURS																42:57
	4		28			21			13			MON	01	5:50	15:21	9:31
	5		29			22			14			TUE	OFF			
	6		30			23			15			WED	02	14:51	22:37	7:46
	7			1		24			16			THU	02	14:51	22:37	7:46
	8			2		25			17			FRI	02	14:51	22:37	7:46
	9			3		26			18			SAT	06	11:00	21:00	10:00
	10			4		27			19			SUN	OFF			
WEEKLY HOURS																42:49
FORTNIGHTLY HOURS																85:46
	11			5		28			20			MON	01	5:50	15:21	9:31
	12			6		29			21			TUE	01	5:50	15:21	9:31
	13			7		30			22			WED	06	12:00	23:00	11:00
	14			8		31			23			THU	02	14:51	22:37	7:46
	15			9			1		24			FRI	02	14:51	22:37	7:46
	16			10			2		25			SAT	OFF			
	17			11			3		26			SUN	OFF			
WEEKLY HOURS																45:34
	18			12			4		27			MON	OFF			
	19			13			5		28			TUE	01	5:50	15:21	9:31
	20			14			6		29			WED	01	5:50	15:21	9:31
	21			15			7		30			THU	01	5:50	15:21	9:31
	22			16			8		31			FRI	01	5:50	15:21	9:31
	23			17			9			1		SAT	OFF			
	24			18			10			2		SUN	OFF			

"extra" instead of on a run, or are detailed there when there are no more runs to pick. Typically new operators just out of training are placed on the extraboard. The board itself is used to cover work that would otherwise be open due to absence of the regularly assigned operator or because the work was not picked. Covering for absences is the primary job of the extraboard.

Often extraboard operators are the newest operators with the least seniority. Operators who begin work at the property between sign-ups usually start on the extraboard because they do not yet have a permanent assignment. Many properties allow operators to select the extraboard with a fixed report time and days off along with other runs during sign-ups. This tends to attract more senior operators who might prefer better days off or a find a more desirable start time on the board.

Many agencies rotate their extraboards. To understand this procedure, think of the extraboard as a collection of slots, each representing an operator. The slots move up the board to an earlier start time every day. The top slot "falls off" and lands at the bottom. In this way operators working the board have the opportunity to work assignments at all times of the day, starting with the latest at the bottom and working up to the earliest at the top. These slots are matched up with open work which is sorted by Transportation dispatchers at each garage from the earliest to latest in starting time order.

An agency may rotate the extraboard by one or more slots each day. The process of rotating the board helps "spread the wealth around" in giving each operator the opportunity to work the better (and often higher-paying) runs along with the less-desirable work. An added benefit is that each operator falling to the bottom gets essentially most of a day off. Consider the operator at the top of the board today who draws an **open run** starting at 4:00 AM and finishing around 1:00 PM. Tomorrow, he/she will be in the bottom slot and may have a 4:00 PM report time.

The work assigned to the board is varied. There are open runs, where the assigned operator might be on the sick list or may have retired. There are show ups, which are assignments to report at a certain time and stand by in case someone "misses out" or phones in sick at the last minute. There are vacation hold-downs, which cover for operators who have picked the week to use one or more of their vacation weeks. There are trippers—and this is where the schedulers come into the picture in a big way. Schedulers have control over the number and types of trippers that will be operated by the extraboard. The number of trippers for the AM and PM peaks must be either balanced **(piece balancing)** or arranged so they complement the other work that the extraboard has to cover. It is always wise for the schedulers to be in touch with each operating garage and understand their staffing situations and what is feasible in the way

Tip Finding ways to encourage more senior operators to sign up for the extraboard is often in the best interest of the property, since these drivers may have a different assignment every day and work best when they have a working knowledge of the system.

open run

A run which was not bid at the previous sign-up or has been vacated during a sign-up due to retirements, terminations, long term illnesses and such.

piece balancing

The process in which the scheduler strives to balance the number of AM and PM pieces to increase the possibility of creating split runs that are in accord with formal and informal rules and to leave a balanced number of AM and PM trippers for the extraboard to cover

show-up

An assignment for an extraboard operator to be at a specific location to fill in for a miss out or to do other work. A certain amount of stand-by time is paid in the event that the operator does not receive a run.

stand-by time

The time that an operator spends at the garage at the agency's direction awaiting assignment of a run or a piece of work. Usually associated with a show-up by an extraboard operator to provide a pool of operators that will be available to fill runs vacated by unscheduled absences.

of trippers that get left for them to fill. While not a common practice, at some agencies the labor agreement or garage staff give schedulers a target for the percentage of work left open.

With regard to filling trippers, some agencies allow operators on regular runs to "bid" trippers during the sign-up. An operator having an AM run finishing by, say, 1:30 PM may choose to regularly work a PM tripper with the hours of 3:50 PM to 6:10 PM. The tripper is worked at overtime, but the advantage to the agency of a regular operator steadily holding the work down is significant. Not all trippers are biddable. In this case the tripper was small enough in hours so it does not put the operator at risk of (a) driving for more hours than a state or federal regulation would allow or (b) having too few hours off between assignments.

Other work includes those **show-ups**, both AM and PM (although enough extraboard operators may be available who can cover both), special service (baseball extras and the like), charters (usually limited these days in the public transit sector so as not to compete with private transportation companies), doctor appointments, union business, and retraining. The list of reasons for absence is longer than this, to be sure, but it falls into two categories: known absences and unexpected absences.

To eliminate as many surprises as possible, agencies require an operator who is sick to call in as soon as possible and get on the sick list. If it is before the time the next day's extraboard is posted (usually around noon), his or her run is placed on the list of open runs to be filled. If the call comes after the next day's extraboard is posted, the run is given to one of the show-up people.

Vacation weeks off must be picked, usually at the sign-up closest to the first of the year. Some systems set out special slots to be bid for vacation hold-downs and keep these separate from the extraboard, while others include vacations with other absences on the extraboard. At a number of systems, one week of vacation can be taken in individual days. These usually require at least a day of prior notification to the dispatcher and may only be granted up to a certain number of operators on a given day.

With all of these efforts to "manage" absences, there are still unexpected no-shows, and for these the show-ups are slotted at times where they have been found through experience to be most helpful. If a show-up does not catch an assignment to fill in on a missing operator's run, then he/she is usually kept on **stand-by** for a predetermined amount of time. If still not assigned, the show-up is given a later report time or a piece of a run during the latter part of the work day.

Dispatchers often get very creative in the use of their show-up operators. It is not unusual for an extraboard operator's day to begin with a 4:45 AM show-up, then an assignment to work an AM tripper from 6:10 to 8:45 AM, followed by a return to the drivers room on stand-by until released at 11:00 AM. That operator will likely be told to return on show-up at 2:00 PM and may catch a second half of a run where its operator has asked for early time off for personal business, or may work a PM tripper, finishing the day around 6:00 PM. On some systems, there is a contractual maximum spread for the extraboard, just as there often is for regular runs. If our example property has a 13-hour spread maximum, then our operator would have to be given an assignment that would finish by 5:45 PM.

Extraboard Sizing

The two main issues with managing an extraboard are (1) proper sizing and (2) assigning the board each day correctly, efficiently, and without any appearance of favoritism. On systems with several garages, there is the added concern for consistency in how assigning is done across the system.

With regard to the first concern, how do we know just what the proper sizing is? Many systems simply go by a percentage that has worked in the past. In the scheduling survey, some agencies reported that their ideal extraboard size is 18%. That is, the number of operators on the extraboard is 18% of the number of operators needed to cover all scheduled runs and **relief runs** at that particular garage. For example, if the total number of runs to be picked at that garage is 282, then the extraboard would have 51 slots for picking.

relief run

A run that is available as a result of other operators' day off selections. Some rosters are made up of several different relief runs.

Is that the correct number? Without an evaluation of agency needs or how they may have changed over time, it is not possible to say. A healthy balance in terms of work distribution on the extraboard is the goal. In operational terms, a healthy balance would mean minimizing both make-up time and overtime. This indicates that the dispatchers are careful not to assign a piece at overtime that could be worked by a show-up operator.

How would an extraboard evaluation be conducted? Each operator on the extraboard is guaranteed 40 hours for their work week. Garage dispatchers are responsible for making certain that those 40 hours are productive and do not have an unusually high amount of make-up time. If make-up time is a regular occurrence, it is a sign there is not enough work for all of the members of the board and that the number of slots should be reduced at the next sign-up. However, if dispatchers are giving make-up time to some while giving significant overtime to other operators on the board, it may be a sign that the board is not being assigned properly—some work assignments are being given to persons who already have enough hours. If there is no make-up time and overtime for the average extraboard operator is becoming excessive, then the extraboard probably needs to be expanded by one or more operators at the next sign-up.

An obvious benefit of including part-time operators on the extraboard is that make-up time is not necessary, providing garage dispatchers with somewhat greater flexibility and possibly reducing agency cost.   However, not all agencies that use part-time operators allow them to be included on the extraboard.   There are great differences in contract provisions related to both the extraboard and the use of part-timers, making it difficult to provide useful information that would apply broadly.

One factor that needs to be considered in an extraboard evaluation is that extraboard operators are additional "bodies" that receive the benefits entitled to their position—benefits that come as a cost. The cost for having extra "bodies" must be weighed against the cost to the agency and the "psychic cost" of excessive overtime and stress on your regular assigned operator staff.

Of course, there are legitimate reasons for extraboard operators to gain overtime. A principal reason is working regular runs which have overtime embodied in them. A healthy rotating board will have a mix of regular open runs and Show-up assignments. Some agencies have rules that an operator who did not get work yesterday is always "first out" for any run that needs to be filled. This is their way of assuring that the work assigned gets balanced to the greatest extent.

A typical approach to sizing the extraboard is to look at the needs of each garage and figure what the average number of extraboard operators should be. You could start with the following list, which is intended to cover weekday work:

Average number of daily absences[1]	17
Vacation reliefs[2]	5
Open runs[3]	6
Miscellaneous[4]	4
Number of balanced AM and PM trippers[5]	19
Total	51

Notes:

[1] *This is the number which experience over the year or the particular season of the sign-up tells us is needed for a typical weekday.*

[2] *This is based on the number of vacation slots that were made available during the week in question or an average for all of the weeks of the sign-up if the number varies by week. Some systems provide a steady number of vacation slots during every week in the year, while others vary the amount, generally making many more weeks available during the summer months, when most operators want to take vacation, than in the winter. Those systems typically cut both peak line service and school trippers during the summer and can afford to let more operators off.*

[3] *Open runs are the known runs which were not bid at the previous sign-up plus the average number of runs that usually get vacated during a sign-up due to retirements, terminations, long-term illnesses and such. Typically, operators may bid on this open work based on their seniority. Other operators may then bid on their work until the least popular work remains uncovered and must be filled daily until the next sign-up.*

[4] *Miscellaneous is a catch-all for missing operators. It could be the average number of operators who are off on union business or must be covered due to random drug testing or retraining. It can also cover the number of individual days that are made available for personal days, birthdays, or single days of vacation. Also, where the use of FMLA (the Family and Medical Leave Act of 1993) is significant, the average number of operators on this leave can be placed here. Wherever these numbers are known, they can be slotted in here.*

[5] *A number of agencies fill many or most of their trippers at overtime, and this would not apply. However, in balancing system costs between overtime and the number of operators to hire (see discussion following), a certain number of trippers may be desirable to fill from the extraboard instead of being bid, and that number is slotted here.*

While our solution works out to the 51 operators we calculated earlier, the list could just as well have produced an altogether different number. The key is to evaluate the use of the extraboard regularly, so a realistic number is always used in sizing the board.[1]

Tip Letting the operator ranks fall below the number needed can be tremendously expensive for an agency and should be cause for major management concern.

Full Staffing

The methodology for calculating extraboard needs is based on an assumption that there are enough trained and available drivers to cover every scheduled assignment and extraboard slot. If not, then dispatchers are constantly in crisis management, mostly resorting to calling in people on their day(s) off to work for missing colleagues. Under this scenario any prior planning of the extraboard is largely thrown out the window, and dispatchers must become diplomatic ambassadors attempting to "sell" the merits of particular assignments to get operators in. Of course, there is always a group of operators who enjoy the overtime and would normally rather work than be off. Almost consistently there is extra work available for this group, but it should not come at the expense of properly sizing and staffing the extraboard.

Ongoing Analysis Steps

To summarize the steps for proper extraboard management:

- Regularly analyze the number of operator slots assigned to the extraboard.
- Research and develop numbers to populate a list of absences similar to the one shown on the previous page.
- Figure out your operator shortages by garage, and make your recruitment plans accordingly.

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[1] The National Center for Transit Research has developed a tool to assist small and mid-sized transit agencies in managing the extraboard. See : http://www.nctr.usf.edu/pdf/77707.pdf.

- Regularly review the daily extraboard assignments and the weekly payroll figures. You are looking to see how well the assignments balanced make-up time and overtime.
- Repeat this process for all of your agency's garages, and look for any manpower imbalance between facilities. These can normally be addressed easily by moving the junior operators from the garage that has more operators than needed to the one that is understaffed. During the few months that new operators are considered "probationary," most agencies are free to move them to any facility where they are needed, with the proviso that additional training on some different vehicle types may be required.

Example of Assigning Extraboard

To demonstrate how extraboard rotation and assignment work, we present a practical example. Following is a list of 20 operators assigned to the extraboard. They are arranged in order of their seniority, and the day shown is theoretically the first weekday of a new sign-up; say, Monday, September 17. During the period when the sign-up is in effect, some operators will retire, some who are currently on short-term or long-term leave will return to work and be slotted onto the board in seniority order, and some of the positions left vacant will not be filled if there is a shortage of operators.

Position	Name	Seniority Date
1	Fillmore, M.	12/28/76
2	Adams, J	2/13/78
3	Harding, W	8/12/80
4	Nixon, R	1/14/81
5	Jackson, A	9/10/84
6	Cleveland, G	3/10/86
7	Arthur, C	9/06/90
8	Monroe, J	8/15/92
9	Taylor, Z	5/03/94
10	Hayes, R.	11/05/97
11	Garfield, J	4/17/98
12	Hoover, H	1/03/00
13	Coolidge, C	2/22/01
14	Johnson, L	6/13/02
15	Grant, U	2/24/04
16	Ford, G	10/01/06
17	Harrison, W	5/15/07
18	Adams, JQ	8/14/07
19	Jefferson, T	12/10/07
20	Van Buren, M	12/10/07

The other piece of information we need is a list of open work to which the extraboard operators will be matched. On this particular day, the list is made up of the following:

Work Assignments for Tuesday, September 18	Report Time	
1	Show-up	4:00 AM
2	Show-up	4:15 AM
3	Show-up	5:00 AM
4	Run 212	5:12 AM
5	Vacation Hold-down 505	5:22 AM
6	Show-up + Run 3609	5:30 AM
7	Run 6801	5:46 AM
8	Run 1510	5:58 AM
9	Show-up + Tripper 959	6:00 AM
10	Vacation Hold-down 2614	6:10 AM
11	Vacation Hold-down 611	6:27 AM
12	Run 1517	9:22 AM
13	Run 612	12:10 PM
14	Show-up + Tripper 1622	1:30 PM
15	Run 3208	1:36 PM
16	Show-up	2:00 PM
17	Run 1014	3:32 PM
18	Run 4419	4:27 PM

The first thing you notice is there are 20 operators on the extraboard and only 18 pieces of work to assign. That is a positive position to be in and is not the normal case, to be sure. But we can use it to illustrate principles better than the “usual” case where there is much more work to be filled than there are operators.

The work falls into broad categories. Experience has indicated we need at least five Show-up positions with show-up times close to where they will be slotted. This gives us coverage throughout the AM pull-out period. We also know that not all Show-ups will be given work, so we can safely assign an open run and a tripper to two of the Show-ups. These are scheduled to pull out about an hour after the on duty time and, if additional people call in sick or **miss out**, there is sufficient opportunity to reassign them to another run and get someone else in to work the previously assigned run.

miss out

The term applied when a scheduled operator does not report on time for his/her assignment.

Another category is Vacation Hold-downs. This garage apparently will allow three operators to be off for vacation each week, so these assignments are being covered by the board. Some agencies separate vacation coverage from the rest of the extraboard, but here it is just one more requirement for the board to hold down.

The runs shown are ones that either did not get bid at the time of the last sign-up and have been left for the dispatcher to fill on a daily basis or have operators assigned who have called in to get on the Sick List. In the latter case, the dispatcher will have to fill the run until the operator calls again and advises that he/she will be returning to work.

Some categories of work are not listed. One or more operators may be assigned for the day for retraining following an accident, or may be listed for a court appearance, or may have asked off on union business. The dispatcher typically will add these in as the board assignment progresses.

Doing the Assignment

Remember we said that the operator line-up on the board was for the first day of the new sign-up on a mythical Monday, September 17. The garage dispatcher on that date will prepare the board for assignment for Tuesday, September 18. The first duty is to rotate the board. This agency rotates one position per day. So, M. Fillmore drops from the number one position down to the bottom at 20. All other operators move up. The top operator is now J. Adams. The dispatcher then aligns the work in time out order (just as we displayed it above). He/she makes a last minute check of the sick list to see if there are any additions or deletions to it (typically operators have a deadline to get on or off the sick list which is about an hour before the next day's assignments are posted). Any changes would be reflected in the mix of runs to fill and the time order of the work to be assigned.

Below is our finished extraboard, which includes the match-up of the open work and also some added work for individual operators as mentioned above.

Position	Name	Assignment	Report Time
2	Adams, J	Show-up	4:00 AM
3	Harding, W	Show-up	4:15 AM
4	Nixon, R	Show-up	5:00 AM
5	Jackson, A	Run 212	5:12 AM
6	Cleveland, G	Vacation Hold-down 505	5:22 AM
7	Arthur, C	Show-up + Run 3609	5:30 AM

Position	Name	Assignment	Report Time
8	Monroe, J	Run 6801	5:46 AM
9	Taylor, Z	Run 1510	5:58 AM
10	Hayes, R.	Show-up + Tripper 959	6:00 AM
11	Garfield, J	Vacation Hold-down 2614	6:10 AM
12	Hoover, H	Vacation Hold-down 611	6:27 AM
13	Coolidge, C	Run 1517	9:22 AM
14	Johnson, L	Show-up	11:00 AM
15	Grant, U	Run 612	12:10 PM
16	Ford, G	Show-up + Tripper 1622	1:30 PM
17	Harrison, W	Retraining—Report 8a-5p	
18	Adams, JQ	Run 3208	1:36 PM
19	Jefferson, T	Show-up	2:00 PM
20	Van Buren, M	Run 1014	3:32 PM
1	Fillmore, M.	Run 4419	4:27 PM

Note that one operator, W. Harrison, was assigned to retraining leaving only one operator with no assignment. L. Johnson was subsequently assigned an 11:00 AM Show-up, which is a nice-to-have protection slot for any afternoon work that might miss out. We would expect this to be a luxury not usually available to the dispatcher. In such cases, he/she would give an 11:00 Show-up to one of the earlier extraboard operators who might not have received any work. Why L. Johnson? Because he was the next operator in seniority that would match up with the 11:00 reporting time. Had the time been made later, an operator who was lower on the board would have caught the assignment.

This is the simple look at assigning extraboards. A number of agencies have various rules governing how the work is given out that are more complicated than shown here. One example rule is that any operator(s) who do not receive a day's work (a run or equivalent) today are automatically guaranteed it for tomorrow (or their next working day). In this case, operators will get out of strict seniority order for this and similar instances. The goal is to spread the work around and minimize the giveaway of unproductive make-up time to get each operator to his/her 40 hour weekly guarantee.

Holidays

Holidays can be a big issue when preparing the runcut for the pick. The labor agreement or past practice (or both) dictates how holidays are addressed. Most agency practices regarding holidays fall into one of the following three options:

- Operators are required to work the holiday if their run operates on the holiday
- Holiday work is posted and picked separately
- The agency determines an appropriate level of service (e.g., Saturday or Sunday) for the holiday, and all operators who have picked that day are required to work on the holiday

More complex situations have evolved from these basic options. One agency had so many operational problems running Saturday schedules on certain holidays that it decided to operate weekday service (modified by pulling a few runs) and pay holiday premium. Another agency assigns all employees two letters from A to G (corresponding to Sunday through Saturday) at the time of initial hire and requires them to work a holiday if the day matches the employee's letter.

Operators need to know the holiday consequences when they pick in order to avoid grievances later. At many agencies, these practices are so traditional they are not well documented, but schedulers should be aware lest their actions have unintended effects. The scheduler should also be aware of the range of options to aid in the assessment of whether the agency's current practice can be improved.

LEVEL 3

End of Rostering.

Rail Scheduling begins on the next page.

Chapter 7.
Rail Scheduling

yard

The rail equivalent of "garage," the place where rail vehicles are stored and maintained.

7.1 Rail Scheduling

Rail scheduling differs from bus scheduling in a number of ways, some subtle and some more wide ranging. At its most basic, rail service must follow a fixed guideway all the way from the storage facility, or **"yard,"** to the beginning of the route. There is much less flexibility in choosing pull-in and pull-out locations, as the guideway dictates how the route will operate. Often, rail lines are scheduled by separate scheduling personnel who are very familiar with rail operations. This helps ensure that all local work rules, conventions, and practices (many of which are not listed in the union contract) are followed. There is also one other major difference between rail and bus: when properly done, schedule makers/operations planners will be consulted by the engineers designing either a new facility or a reconstructed terminal early in the design process, and will ask—both operations and operations planners/schedulers—what a preferred terminal layout/track arrangement might be, space and budget permitting.

There are almost as many variations within rail scheduling as there are between rail and bus scheduling. Many of these variations are tied to the type of rail operation being scheduled. High platform rapid transit lines, often referred to as "Heavy Rail," use a different approach from light rail or surface streetcar lines. Commuter rail is different altogether. Even among heavy rail operators, each approach is somewhat unique to the respective system. Invariably, though, many of these operational differences are at the terminal and the system's approach is a response to the civil/track design of the particular terminal. This is why active participation in terminal design is an important role for the schedule department to play. Judicious capital investment at the beginning can pay operating budget dividends, or simply provide more reliable, quality service to customers.

Much has been written elsewhere about what constitutes a "heavy" versus "light" rail system or even a streetcar line, as some rail systems have the characteristics of each. For our purposes, we define heavy rail as:

- Operating on segregated rights-of-way, often on elevated structures or in subway.
- Boarding from high platforms.
- Serving complex stations where passengers cannot cross tracks, but must go up (or down), over or under to reach other platforms.
- Running as many as ten cars in a single train, under the control of a train operator and (on some systems) a conductor.
- The rail cars themselves in a heavy rail system will have operable end doors, which permit passage from car-to-car in a multi-car trainset. (Many systems may lock these doors to prevent rider passage from car to car for security reasons, but the doors, nonetheless, are operable and an integral part of the car body's design.)

Light rail, on the other hand is an upgraded version of streetcar lines, sometimes on segregated rights-of-way but often operating in the street in mixed traffic for at least part of their route. Station designs are usually simple, with low platforms and the ability to walk across tracks to enter or exit the station. "Trains" are often one car long, and when longer (e.g., two or three cars) passengers cannot cross from car-to-car on-board the train as there aren't any doors at the car ends to pass through. Therefore, scheduling for light rail comes closer to bus scheduling in approach.

To keep the size of this chapter manageable and to impart as much useful information as possible about rail scheduling techniques, we will focus on light rail, a fast-growing mode in North America, and add comments where appropriate on the differences for other rail modes.

Ways in which rail scheduling differs from bus scheduling:

- Pull-on and pull-off trips must follow the rails and are usually scheduled into the timetable so that they are accounted for. This is especially important if there is a large amount of single track on the rail system.
- The scheduler must be familiar with the track structure: the layout of junctions, locations of crossovers, number of tracks at each terminal station or intermediate stations where train turnbacks may be scheduled and whether crossovers are located in front of or behind the platforms at the terminal station. He/she should also have a basic familiarity with the signal system and such details as how close a headway the system will support. There is no reason to schedule trains one minute apart if the signal system will not allow it. It has been learned through experience that most signal systems, wayside and otherwise, cannot handle headways[1] closer than every two minutes for sustained periods (more than 20–30 minutes). The primary reason for this is station dwell activity (boarding and alighting) that itself approaches—or exceeds—two minutes. There are other reasons as well, but a discussion of this topic (practical rail headways) is beyond the scope of this manual.
- Rail schedules often have one time point for each station, resulting in more timepoints than are found on a typical bus schedule. This makes computerized scheduling that much more appealing.
- All heavy rail and most light rail involve scheduling trains, which are mostly made up of more than one car. (The number of cars in a train is called a **consist** (pronounced CON-sist), i.e., a four car train is a four car consist.) On light rail systems especially and on some heavy rail systems, cars will be added and cut from the train as the day pro-

consist

(pronounced CON-sist) A term that refers collectively to the rail cars comprising a train, i.e., a four car train is a four car consist.

drop-back

A technique where the operator or train crew gets off an arriving vehicle at a terminal, takes layover, and assumes operation of the next vehicle to arrive. Most common on frequent rail lines where close headways do not allow sufficient layover time for the train crew, this technique is also used for special events to maximize the number of trains in service. If service is very frequent, the train crew may not board the next train but instead the train after that; this is called a "double drop-back." Some agencies use the term "fall-back" instead.

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[1] Recall that frequency is the inverse of headway: a headway of 2 minutes is equivalent to a frequency of one train every two minutes, or 30 trains per hour.

meet

Two trains, on two different tracks (in single-track operation, one train is on a passing siding), converging at the same location.

yard balancing

The process of ensuring that the number of train cars pulling into a specific yard at the end of the service day equals the number that pulled out at the beginning of the service day. On rail lines served by more than one yard, the same vehicles do not necessarily return to the same yard. Only the count in each yard must be the same at the end of the day as the beginning.

banging out the schedule

A rail scheduling term for the process of scheduling trips on lines that share a common segment in such a way that spaces the trains on the common segment. If the spaces on the common segment are evenly apart this is the rail equivalent of "intertiming."

gresses. These changes are typically tracked by the scheduler who keeps up with the car count, much as he/she tracks the bus count on a bus schedule.

- Rail systems often make widespread use of "**drop-backs**" at the ends of their routes. A drop-back occurs when the arriving "crew" (a crew can be just one person, the train operator, or also the conductor) gets off the train and waits one or more departing trains before once again assuming operation of a train. This invariably means that there are more active crews in the cycle than active consists.
- Rail lines are more likely to have fewer running time changes. In some cases, the running time is the same all day. In fact, on systems with a lot of single track with passing sidings, a single running time is a necessity in order to assure that **meets** occur at regular intervals. On sections operating in mixed traffic, running times are set using the same procedures described earlier for bus routes, and may change throughout the day.
- Longer-length rail lines will often have yards on both ends of the line in order to cut down on the amount of time and mileage for nonessential trips that just serve to get out of or into the yard. In many cases trains are put into service heading to the nearest terminal and later pulled in from the nearest terminal, which may not be the one from which it went into service.[2] For this reason, schedulers have to keep track of yard counts as well as car and train counts. The schedule should always get the same number of cars back to each respective yard as it provided at the beginning of the operating day. Otherwise, Maintenance personnel may have to make expensive yard deadhead moves in the middle of the night. This attention to yard count is called **"Yard Balancing."**
- On systems where routes merge and diverge (as contrasted with routes that are self-contained), special care must be taken to schedule trains so they flawlessly intersperse with the other route's trains. To leave this to chance is to experience delays with trains waiting out red signals while the other train crosses in front of it or pulls ahead of it. On one large system, the process of making sure that schedules for different subway lines merge properly is known as **"banging out" the schedule** and this follows the writing of the individual timetables.

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[2] For the most part, unlike buses which are assigned to a particular depot for maintenance purposes—and need to go "home" in order to be maintained—rail cars are assigned to a line (or sometimes shared between lines). Rail maintenance is line-based, and it is the maintenance department that determines how, when, and where—working with Transportation (and in some places, with Scheduling)—individual cars on a line will be maintained.

Despite these differences, scheduling of rail service bears a lot of similarities to bus scheduling. This is particularly true in the following ways:

- Scheduling rail service is still a matter of making supply available to meet demand based on rider information and service standards at a maximum load point.
- Trips are scheduled the same once the headway by time of day is known. It is an obvious point (worth repeating nonetheless) that differing services running on the same track must have the same headway or combinations of differing headways that allow sufficient clear track between trains. As mentioned above, practical operation and signal systems rarely allow for trains to be closer than two minutes apart. On most heavy rail lines and light rail lines that run on private right-of-way, this rule is enforced by cab signal systems, which will automatically brake the train if one gets too close to the one ahead.

  Under what circumstances would differing headways be appealing? The most common situation is when every other trip on a line turns short of the normal route end. Giving the short-turn trips a wider headway will often even out ridership levels between through and short turn vehicles. For example, if a line has a 7.5-minute headway, the trips could be arranged to operate 6 and 9. Under a 6 and 9 headway, the train from the more distant terminal would leave, followed by a short-line trip nine minutes later, and then followed by a long (more distant terminal) trip six minutes later. With more passenger boardings within the common segment likely to be on the short trip (assuming random arrival at the station), this mix would even out loads.
- Headways usually differ by time of day and service ramps up and down, into and out of the peaks just as it does for bus schedules. That said, there is probably greater use of clockface headways on light rail lines (e.g., same times past the hour seven days a week) than on buses.
- Rail trips are blocked the same as bus trips. The resulting blocks are often referred to as **"train blocks"** to differentiate them from **"crew blocks"** which may not follow the same train all day, particularly if a drop-back is scheduled for the crews at one or both ends of the route.

With that in mind, the novice scheduler should not be afraid to try his or her hand with a rail schedule. Most of what you have learned to this point will hold true through the process of building trips and blocking them into "train blocks."

Route 100-Light Rail is a typical schedule for a rail line operating from the west side of a city, through the downtown area to the east side. Some of the line is on streets in mixed or segre-

train block

The series of trips operated by each train from the time it pulls out to the time it pulls in. A complete block includes a pull-out trip from the yard followed by one or (usually) more revenue trips and concluding with a pull-in trip back to the yard.

crew block

The series of trips operated by each train crew from pull-out to pull-in. The crew block will differ from the train block if drop-backs are scheduled for the crews.

Tip Be aware of the number of trains that could be at a given terminal at the same time. If two tracks are available at the terminal, the train on track one should depart at least two minutes before the scheduled arrival of the next train to use track one. This translates to a maximum layover at a terminal equal to:

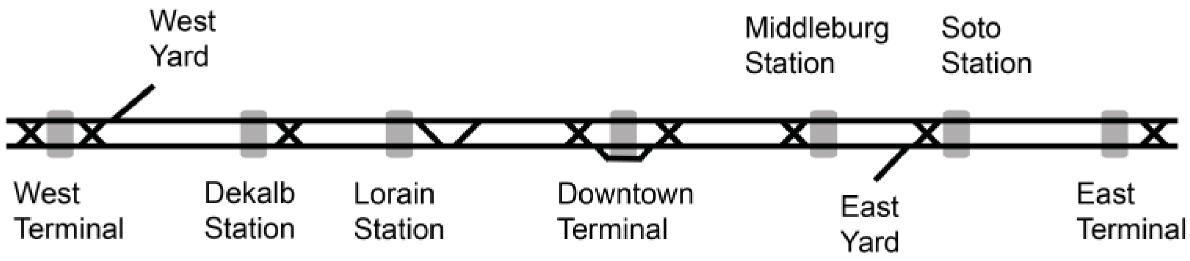
*HEADWAY (in minutes) * NO. OF TRACKS AT TERMINAL STATION – 2*

gated traffic, mostly in the downtown area, while much of the outer portion of line is on its own right-of-way.

While this background information should be helpful in giving the scheduler a mental picture of the line, its relevance to producing a schedule is that the schedule will be kept relatively simple, as rail schedules go, and many of the steps and techniques learned earlier will be followed, with emphasis on the new tasks.

The service pattern for Route 100 calls for a mostly uniform 15-minute service for peak hours and 20 minutes during the midday period. During these times, a short-turn service is interspersed between these trains to provide double the service. Turnback locations are at both the west (Dekalb Station) and east (Soto Station) sides of the line as shown in the Route 100 Light Rail Track Diagram below. During early morning and evenings, these short turns do not run, and a 15-minute headway is provided end to end except for the earliest and latest trips of the day. All segments of this line are double track, so keeping a watchful eye on where trains meet is not a factor in this example.

Route 100 - Light Rail Track Diagram



One important factor is the number of trains that could be at either end terminal at one time. Since the end stations feature two tracks with a middle passenger platform (a somewhat standard arrangement—for further discussion of terminal design and its relationship to scheduling, see Terminal Design and Scheduling Efficiency at the end of this chapter), the rule is to have the first train depart well before (at least two minutes is a good time “cushion”) the third train is scheduled into the terminal. This will place limits on the amount of layover that can be scheduled. With 15-minute headways as the most frequent service level at end terminals, this will not be a problem in our example. Calculating double the headway (representing the availability of two tracks) minus the two minutes (safety and reliability factor), layover could extend to as much as 28 minutes, which is well beyond any reasonable amount we would want to give.

As is often the case with actual light rail lines of this cross-city design, storage yards are provided at or near each end of the line on our example schedule. The West Yard is located adjacent to the West Station. On the east end another yard is located near the Soto Station. When blocking, the two yards will add a level of complication to the effort, which we will see later.

Calculating Two Round-trip Cycles

As in bus scheduling, we start with our round-trip cycle calculation, but in this example we have a complication introduced by the short-turn operation. The way to address this is to look at the full route cycle first. It always has to work before working on the short cycle. So, work on the long cycle first, and then address the short cycle.

For the base period (which includes early morning and evening) the round-trip running time is 46 + 46 = 92, before layover time is added. The headway on the long cycle is 15 minutes in the early morning and evening periods (when all trains operate the entire length of the line) and 20 minutes in the midday period.

Consider the midday period first. A 20-minute headway yields potential round-trip **cycle times** of 80, 100, and 120. The 92 minutes of round-trip running time would fit into a 100-minute cycle, leaving eight minutes per round trip for layover. Although that number is below the 10% usually considered as minimum, we could opt to turn the trains in 100 minutes and stretch the crews by scheduling them to drop-back one train at one of the terminals. This would save a two-car train from the schedule. Viewed from a numbers standpoint, there would be five trains and six crews operating on the long cycle.

On the other hand, drop-backs have their disadvantages. They almost always require some supervision; they can promote conditions where a train sits at a stop or platform without boarding passengers or which boards passengers but has no crew on board. Supervision can overcome some drawbacks, but if possible, it is almost always preferable to schedule enough layover in the cycle and leave crews on their trains.

Therefore, in our example above we go for the 120-minute cycle time and schedule six trains to the full route trips. If we build trips with leaving times starting on the hour from both terminals, the layover is evenly distributed with 14 minutes available at each end. Sample roundtrips are shown below, confirming that the layover times work as expected and that six blocks are needed.

cycle time

Sum of the round trip running time plus layover time. This is also known as “round-trip cycle time.”

HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

DIRECTION = EAST-WEST

	A	B	C	D	E	F	G				G	F	E	D	C	B	A	
	WEST	DEKALB	LORAIN	DNTWN	MIDDLE	SOTO	EAST				EAST	SOTO	MIDDLE	DNTWN	LORAIN	DEKALB	WEST	
BLOCK	TERM	STA	STA	TERM	BURG	STA	TERM	LVE.		BLOCK	TERM	STA	BURG	TERM	STA	STA	TERM	LVE.
1	9:20						10:06	10:20		1	10:20						11:06	11:20
2	9:40						10:26	10:40		2	10:40						11:26	11:40
3	10:00						10:46	11:00		3	11:00						11:46	12:00
4	10:20						11:06	11:20		4	11:20						12:06	12:20
5	10:40						11:26	11:40		5	11:40						12:26	12:40
6	11:00						11:46	12:00		6	12:00						12:46	13:00
1	11:20						12:06	12:20		1	12:20						13:06	13:20

We could follow this same cycle for early and late trips using eight trains for the 15-minute service. This is one more train than we could get away with in the cycle. A 105-minute cycle would yield 13 minutes of layover, which would amply meet our 10%, but would affect our ability to leave on the hour and at easily remembered times (:15, ;30, :45) from both terminals. While it might be desirable to give up on these departure times to produce significant savings, the duration of the early and late trips is not long enough to produce significant savings of vehicle and platform hours.   Sample roundtrips in the evening are shown below.

HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

DIRECTION = EAST-WEST

	A	B	C	D	E	F	G				G	F	E	D	C	B	A	
	WEST	DEKALB	LORAIN	DNTWN	MIDDLE	SOTO	EAST				EAST	SOTO	MIDDLE	DNTWN	LORAIN	DEKALB	WEST	
BLOCK	TERM	STA	STA	TERM	BURG	STA	TERM	LVE.		BLOCK	TERM	STA	BURG	TERM	STA	STA	TERM	LVE.
1	19:00						19:46	20:00		1	20:00						20:46	21:00
2	19:15						20:01	20:15		2	20:15						21:01	21:15
3	19:30						20:16	20:30		3	20:30						21:16	21:30
4	19:45						20:31	20:45		4	20:45						21:31	21:45
5	20:00						20:46	21:00		5	21:00						21:46	22:00
6	20:15						21:01	21:15		6	21:15						22:01	22:15
7	20:30						21:16	21:30		7	21:30						22:16	22:30
8	20:45						21:31	21:45		8	21:45						22:31	22:45
1	21:00						21:46	22:00		1	22:00						22:46	23:00

Now we look at peak cycles for the long trips. The round-trip running time in the peak is 50 + 50 = 100, which continues to work within our 120-minute cycle. It produces 10 minutes of layover at each terminal. This is more than enough so that drop-backs do not need to be considered. Sample long trips for the peak are:

HEADWAY SHEET

Line 100 - Light Rail IN EFF: Fall 2008
MONDAY THRU FRIDAY

DIRECTION = EAST-WEST

	A	B	C	D	E	F	G				G	F	E	D	C	B	A	
	WEST	DEKALB	LORAIN	DNTWN	MIDDLE	SOTO	EAST				EAST	SOTO	MIDDLE	DNTWN	LORAIN	DEKALB	WEST	
BLOCK	TERM	STA	STA	TERM	BURG	STA	TERM	LVE.		BLOCK	TERM	STA	BURG	TERM	STA	STA	TERM	LVE.
1	6:00						6:50	7:00		1	7:00						7:50	8:00
2	6:15						7:05	7:15		2	7:15						8:05	8:15
3	6:30						7:20	7:30		3	7:30						8:20	8:30
4	6:45						7:35	7:45		4	7:45						8:35	8:45
5	7:00						7:50	8:00		5	8:00						8:50	9:00
6	7:15						8:05	8:15		6	8:15						9:05	9:20
7	7:30						8:20	8:30		7	8:30						9:20	
8	7:45						8:35	8:45		8	8:45						9:35	9:40
1	8:00						8:50	9:00		1	9:00						9:50	10:00

Once we are satisfied with the long trips, we look at the short cycle. Round-trip running time on the short cycle for the base is 31 + 31 = 62. A 20-minute headway yields cycles of 60, 80, and 100. 60 is too short. 80 would give us 18 minutes to divide between both turnback terminals. We write a few trips exactly fitting in between the long trips and note that they give us eight minutes at Soto Station on the east and 10 minutes at Dekalb Station on the west. It seems ideal for our purposes.

In the example below, letters are used to denote short blocks to make it easier to see how they fit into the schedule (this would not be done in a typical blocking scheme). Also, the introduction of the short-turn trips means that the blocks no longer line up evenly across each row when trips are sorted by time at common stations.

HEADWAY SHEET

Line 100 - Light Rail IN EFF: Fall 2008
MONDAY THRU FRIDAY

DIRECTION = EAST-WEST

	A	B	C	D	E	F	G				G	F	E	D	C	B	A	
BLOCK	WEST TERM	DEKALB STA	LORAIN STA	DNTWN TERM	MIDDLE BURG	SOTO STA	EAST TERM	LVE.		BLOCK	EAST TERM	SOTO STA	MIDDLE BURG	DNTWN TERM	LORAIN STA	DEKALB STA	WEST TERM	LVE.
										A		10:17				10:48		10:58
1	9:20	9:28				9:59	10:06	10:20		1	10:20	10:27				10:58	11:06	11:20
A		9:38				10:09		10:17		B		10:37				11:08		11:18
2	9:40	9:48				10:19	10:26	10:40		2	10:40	10:47				11:18	11:26	11:40
B		9:58				10:29		10:37		C		10:57				11:28		11:38
3	10:00	10:08				10:39	10:46	11:00		3	11:00	11:07				11:38	11:46	12:00
C		10:18				10:49		10:57		D		11:17				11:48		11:58
4	10:20	10:28				10:59	11:06	11:20		4	11:20	11:27				11:58	12:06	12:20

Finally, the short trips in the peak cycle require a decision: where to place them in between the long trips—either seven or eight minutes after the former. While one minute may not seem like much, the general rule is to give the greater headway to the short trip. In fact, if loads between the two trip patterns become unbalanced, we might want to consider a 9 and 6 split, with the short trip gaining the wider headway (i.e., leaving nine minutes after the long trip). In this case a simple 8-7 should work fine.

The short round-trip running time in the peak periods is 33 + 33 = 66. At a 15-minute headway, the first cycle time to consider is 75, which experience tells us is too little layover and would produce an even headway in only one direction. We can assure ourselves of our hunch by building some trips that meet this layover constraint.

HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

DIRECTION = EAST-WEST

	A	B	C	D	E	F	G				G	F	E	D	C	B	A	
	WEST	DEKALB	LORAIN	DNTWN	MIDDLE	SOTO	EAST				EAST	SOTO	MIDDLE	DNTWN	LORAIN	DEKALB	WEST	
BLOCK	TERM	STA	STA	TERM	BURG	STA	TERM	LVE.		BLOCK	TERM	STA	BURG	TERM	STA	STA	TERM	LVE.
										A		6:55				7:28		7:32
1	6:00	6:09				6:42	6:50	7:00		1	7:00	7:08				7:41	7:50	8:00
A		6:17				6:50		6:55		B		7:10				7:43		7:47
2	6:15	6:24				6:57	7:05	7:15		2	7:15	7:23				7:56	8:05	8:15
B		6:32				7:05		7:10		C		7:25				7:58		8:02
3	6:30	6:39				7:12	7:20	7:30		3	7:30	7:38				8:11	8:20	8:30
C		6:47				7:20		7:25		D		7:40				8:13		8:17

Sure enough, in the other direction from the even trips, short trips are almost on top of the long trips, as highlighted. So, we settle for the next multiple of 15, which is 90. This gives us 24 minutes to be divided between the two turnback terminals. We build some sample trips eight minutes after the through trips in each direction and see that the layover falls out as 11 minutes at Soto and 13 at Dekalb. This works well.

HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

DIRECTION = EAST-WEST

	A	B	C	D	E	F	G				G	F	E	D	C	B	A	
	WEST	DEKALB	LORAIN	DNTWN	MIDDLE	SOTO	EAST				EAST	SOTO	MIDDLE	DNTWN	LORAIN	DEKALB	WEST	
BLOCK	TERM	STA	STA	TERM	BURG	STA	TERM	LVE.		BLOCK	TERM	STA	BURG	TERM	STA	STA	TERM	LVE.
										A		7:01				7:34		7:47
1	6:00	6:09				6:42	6:50	7:00		1	7:00	7:08				7:41	7:50	8:00
A		6:17				6:50		7:01		B		7:16				7:49		8:02
2	6:15	6:24				6:57	7:05	7:15		2	7:15	7:23				7:56	8:05	8:15
B		6:32				7:05		7:16		C		7:31				8:04		8:17
3	6:30	6:39				7:12	7:20	7:30		3	7:30	7:38				8:11	8:20	8:30
C		6:47				7:20		7:31		D		7:46				8:19		8:32

Building the Trips

So far, this is looking very much like the preparation of a bus schedule, other than thoughts we have considered regarding layover strategy. The schedule is somewhat formulaic in that we have tried to stay to even, hour-based leaving times from terminals during most times of the day (1) because we could without undue extra cost and (2) as a marketing point for the "convenience" of the light rail service.

We can start building trips now that we have our cycles in mind. The only other piece of information we need is the span of service and times for running each headway and service pattern. Those instructions are as follows:

Route 100 – Light Rail Service Plan	
Span of Service	4:30 AM until 12 midnight
Early AM/Late PM headways	30 minutes 4:30-5A, 11-12Mid 15 min, 5-6A, 7-11P long only
Peak headways	7/8 min, 6-9A, 3-7P 15 long, 15 short
Base headways	10 min, 9A-3P, 20 long, 20 short

To be simple, start trips from each direction at 4:30 AM and build onward from there. If you are building trips using either a spreadsheet or a scheduling package, you want to build the long trips first, then go back and insert the short trips. Note that the Schedule Sheet is divided in two with each direction having its own side independent of the other. The reason for this is the short trips, which do not line up across the page as their cycle is two trains shorter.

Keep in mind that you have variable running time on this schedule. Use the Peak running times during the times that have been designated above as Peak for headway purposes. The transition to peak headway and running times can be scheduled to occur at the same time. You might want to do some running time smoothing after you construct your trips, since the combination of the two changes does produce a noticeable gap in the headway. We have shaded the trips where we manually "smoothed" the running time transition in order to minimize the gaps.

Once you finish, you should have a schedule that looks approximately like our example, again, not much different than a bus schedule at this point. The next step is to block the schedule.

HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

Part 1

DIRECTION = EAST-WEST

	A	B	C	D	E	F	G				G	F	E	D	C	B	A	
	WEST	DEKALB	LORAIN	DNTWN	MIDDLE	SOTO	EAST				EAST	SOTO	MIDDLE	DNTWN	LORAIN	DEKALB	WEST	
BLOCK	TERM	STA	STA	TERM	BURG	STA	TERM	LVE.		BLOCK	TERM	STA	BURG	TERM	STA	STA	TERM	LVE.
						4:18	4:25	4:30			4:30	4:37	4:42	4:51	5:02	5:08	5:16	5:30
						4:48	4:55	5:00			5:00	5:07	5:12	5:21	5:32	5:38	5:46	6:00
						5:03	5:10	5:15			5:15	5:22	5:27	5:36	5:47	5:53	6:01	6:15
	4:30	4:38	4:44	4:55	5:04	5:09	5:16	5:30			5:30	5:37	5:42	5:51	6:02	6:08	6:16	6:30
						5:33	5:40	5:45			5:45	5:52	5:57	6:06	6:17	6:23	6:31	6:45
	5:00	5:08	5:14	5:25	5:34	5:39	5:46	6:00				6:00	6:05	6:15	6:26	6:33		6:47
	5:15	5:23	5:29	5:40	5:49	5:54	6:01	6:15			6:00	6:08	6:13	6:23	6:34	6:41	6:50	7:00
	5:30	5:38	5:44	5:55	6:04	6:09	6:16	6:30				6:16	6:21	6:31	6:42	6:49		7:02
	5:45	5:53	5:59	6:10	6:19	6:24	6:31	6:45			6:15	6:23	6:28	6:38	6:49	6:56	7:05	7:15
	5:53	6:01	6:07	6:18	6:28	6:33		6:46				6:31	6:36	6:46	6:57	7:04		7:17
	6:00	6:09	6:16	6:27	6:37	6:42	6:50	7:00			6:30	6:38	6:43	6:53	7:04	7:11	7:20	7:30
	6:08	6:17	6:24	6:35	6:45	6:50		7:01				6:46	6:51	7:01	7:12	7:19		7:32
	6:15	6:24	6:31	6:42	6:52	6:57	7:05	7:15			6:45	6:53	6:58	7:08	7:19	7:26	7:35	7:45
	6:23	6:32	6:39	6:50	7:00	7:05		7:16				7:01	7:06	7:16	7:27	7:34		7:47
	6:30	6:39	6:46	6:57	7:07	7:12	7:20	7:30			7:00	7:08	7:13	7:23	7:34	7:41	7:50	8:00
		6:47	6:54	7:05	7:15	7:20		7:31				7:16	7:21	7:31	7:42	7:49		8:02
	6:45	6:54	7:01	7:12	7:22	7:27	7:35	7:45			7:15	7:23	7:28	7:38	7:49	7:56	8:05	8:15
		7:02	7:09	7:20	7:30	7:35		7:46				7:31	7:36	7:46	7:57	8:04		8:17
	7:00	7:09	7:16	7:27	7:37	7:42	7:50	8:00			7:30	7:38	7:43	7:53	8:04	8:11	8:20	8:30
		7:17	7:24	7:35	7:45	7:50		8:01				7:46	7:51	8:01	8:12	8:19		8:32
	7:15	7:24	7:31	7:42	7:52	7:57	8:05	8:15			7:45	7:53	7:58	8:08	8:19	8:26	8:35	8:45
		7:32	7:39	7:50	8:00	8:05		8:16				8:01	8:06	8:16	8:27	8:34		8:47
	7:30	7:39	7:46	7:57	8:07	8:12	8:20	8:30			8:00	8:08	8:13	8:23	8:34	8:41	8:50	9:00
		7:47	7:54	8:05	8:15	8:20		8:31				8:16	8:21	8:31	8:42	8:49		9:02
	7:45	7:54	8:01	8:12	8:22	8:27	8:35	8:45			8:15	8:23	8:28	8:38	8:49	8:56	9:05	9:20
		8:02	8:09	8:20	8:30	8:35		8:46				8:31	8:36	8:46	8:57	9:04		9:18
	8:00	8:09	8:16	8:27	8:37	8:42	8:50	9:00			8:30	8:38	8:43	8:53	9:04	9:11	9:20	
		8:17	8:24	8:35	8:45	8:50		9:01				8:46	8:51	9:01	9:12	9:19	9:28	
	8:15	8:24	8:31	8:42	8:52	8:57	9:05	9:20			8:45	8:53	8:58	9:08	9:19	9:26	9:35	9:40
		8:32	8:39	8:50	9:00	9:05		9:16				9:01	9:06	9:16	9:27	9:34		9:38
	8:30	8:39	8:46	8:57	9:07	9:12	9:20	9:40			9:00	9:08	9:13	9:23	9:34	9:41	9:50	10:00
		8:47	8:54	9:05	9:15	9:20		9:37				9:16	9:21	9:31	9:42	9:49		9:58
	8:45	8:54	9:01	9:12	9:22	9:27	9:35	9:41			9:20	9:27	9:32	9:41	9:52	9:58	10:06	10:20
		9:02	9:09	9:20	9:30	9:35						9:37	9:42	9:51	10:02	10:08		10:18
	9:00	9:09	9:16	9:27	9:37	9:42	9:50	10:00			9:40	9:47	9:52	10:01	10:12	10:18	10:26	10:40
		9:18	9:24	9:35	9:44	9:49		9:57			9:41	9:48						
	9:20	9:28	9:34	9:45	9:54	9:59	10:06	10:20				9:57	10:02	10:11	10:22	10:28		10:38
		9:38	9:44	9:55	10:04	10:09		10:17			10:00	10:07	10:12	10:21	10:32	10:38	10:46	11:00
	9:40	9:48	9:54	10:05	10:14	10:19	10:26	10:40				10:17	10:22	10:31	10:42	10:48		10:58
		9:58	10:04	10:15	10:24	10:29		10:37			10:20	10:27	10:32	10:41	10:52	10:58	11:06	11:20
	10:00	10:08	10:14	10:25	10:34	10:39	10:46	11:00				10:37	10:42	10:51	11:02	11:08		11:18
		10:18	10:24	10:35	10:44	10:49		10:57			10:40	10:47	10:52	11:01	11:12	11:18	11:26	11:40
	10:20	10:28	10:34	10:45	10:54	10:59	11:06	11:20				10:57	11:02	11:11	11:22	11:28		11:38
		10:38	10:44	10:55	11:04	11:09		11:17			11:00	11:07	11:12	11:21	11:32	11:38	11:46	12:00
	10:40	10:48	10:54	11:05	11:14	11:19	11:26	11:40				11:17	11:22	11:31	11:42	11:48		11:58
		10:58	11:04	11:15	11:24	11:29		11:37			11:20	11:27	11:32	11:41	11:52	11:58	12:06	12:20
	11:00	11:08	11:14	11:25	11:34	11:39	11:46	12:00				11:37	11:42	11:51	12:02	12:08		12:18
		11:18	11:24	11:35	11:44	11:49		11:57			11:40	11:47	11:52	12:01	12:12	12:18	12:26	12:40
	11:20	11:28	11:34	11:45	11:54	11:59	12:06	12:20				11:57	12:02	12:11	12:22	12:28		12:38
		11:38	11:44	11:55	12:04	12:09		12:17			12:00	12:07	12:12	12:21	12:32	12:38	12:46	13:00
	11:40	11:48	11:54	12:05	12:14	12:19	12:26	12:40				12:17	12:22	12:31	12:42	12:48		12:58
		11:58	12:04	12:15	12:24	12:29		12:37			12:20	12:27	12:32	12:41	12:52	12:58	13:06	13:20
	12:00	12:08	12:14	12:25	12:34	12:39	12:46	13:00				12:37	12:42	12:51	13:02	13:08		13:18
		12:18	12:24	12:35	12:44	12:49		12:57			12:40	12:47	12:52	13:01	13:12	13:18	13:26	13:40
	12:20	12:28	12:34	12:45	12:54	12:59	13:06	13:20				12:57	13:02	13:11	13:22	13:28		13:38
		12:38	12:44	12:55	13:04	13:09		13:17			13:00	13:07	13:12	13:21	13:32	13:38	13:46	14:00
	12:40	12:48	12:54	13:05	13:14	13:19	13:26	13:40				13:17	13:22	13:31	13:42	13:48		13:58
		12:58	13:04	13:15	13:24	13:29		13:37			13:20	13:27	13:32	13:41	13:52	13:58	14:06	14:20
	13:00	13:08	13:14	13:25	13:34	13:39	13:46	14:00				13:37	13:42	13:51	14:02	14:08		14:18
		13:18	13:24	13:35	13:44	13:49		13:57			13:40	13:47	13:52	14:01	14:12	14:18	14:26	14:40
	13:20	13:28	13:34	13:45	13:54	13:59	14:06	14:20				13:57	14:02	14:11	14:22	14:28		14:38

HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

Part 2

DIRECTION = EAST-WEST

	A	B	C	D	E	F	G				G	F	E	D	C	B	A	
	WEST	DEKALB	LORAIN	DNTWN	MIDDLE	SOTO	EAST				EAST	SOTO	MIDDLE	DNTWN	LORAIN	DEKALB	WEST	
BLOCK	TERM	STA	STA	TERM	BURG	STA	TERM	LVE.		BLOCK	TERM	STA	BURG	TERM	STA	STA	TERM	LVE.
		13:38	13:44	13:55	14:04	14:09		14:17			14:00	14:07	14:12	14:21	14:32	14:38	14:46	15:00
	13:40	13:48	13:54	14:05	14:14	14:19	14:26	14:40				14:17	14:22	14:31	14:42	14:48		14:59
		13:58	14:04	14:15	14:24	14:29		14:37			14:20	14:27	14:32	14:41	14:52	14:58	15:06	15:15
	14:00	14:08	14:14	14:25	14:34	14:39	14:46	15:00				14:37	14:42	14:52	15:03	15:09		15:17
		14:18	14:24	14:35	14:44	14:49		14:58			14:40	14:47	14:52	15:02	15:13	15:20	15:28	15:45
	14:20	14:28	14:34	14:45	14:54	14:59	15:06	15:15				14:58	15:03	15:13	15:24	15:31		15:47
		14:38	14:44	14:55	15:04	15:09		15:16			15:00	15:08	15:13	15:23	15:34	15:41	15:50	16:00
						15:15	15:23	15:30				15:16	15:21	15:31	15:42	15:49		16:02
	14:40	14:48	14:54	15:05	15:15	15:20	15:28	15:45			15:15	15:23	15:28	15:38	15:49	15:56	16:05	16:15
		14:59	15:06	15:17	15:27	15:32		15:46				15:31	15:36	15:46	15:57	16:04		16:17
	15:00	15:09	15:16	15:27	15:37	15:42	15:50	16:00			15:30	15:38	15:43	15:53	16:04	16:11	16:20	16:30
		15:17	15:24	15:35	15:45	15:50		16:01				15:46	15:51	16:01	16:12	16:19		16:32
	15:15	15:24	15:31	15:42	15:52	15:57	16:05	16:15			15:45	15:53	15:58	16:08	16:19	16:26	16:35	16:45
	15:23	15:32	15:39	15:50	16:00	16:05		16:16				16:01	16:06	16:16	16:27	16:34		16:47
	15:30	15:39	15:46	15:57	16:07	16:12	16:20	16:30			16:00	16:08	16:13	16:23	16:34	16:41	16:50	17:00
		15:47	15:54	16:05	16:15	16:20		16:31				16:16	16:21	16:31	16:42	16:49		17:02
	15:45	15:54	16:01	16:12	16:22	16:27	16:35	16:45			16:15	16:23	16:28	16:38	16:49	16:56	17:05	17:15
		16:02	16:09	16:20	16:30	16:35		16:46				16:31	16:36	16:46	16:57	17:04		17:17
	16:00	16:09	16:16	16:27	16:37	16:42	16:50	17:00			16:30	16:38	16:43	16:53	17:04	17:11	17:20	17:30
		16:17	16:24	16:35	16:45	16:50		17:01				16:46	16:51	17:01	17:12	17:19		17:32
	16:15	16:24	16:31	16:42	16:52	16:57	17:05	17:15			16:45	16:53	16:58	17:08	17:19	17:26	17:35	17:45
		16:32	16:39	16:50	17:00	17:05		17:16				17:01	17:06	17:16	17:27	17:34		17:47
	16:30	16:39	16:46	16:57	17:07	17:12	17:20	17:30			17:00	17:08	17:13	17:23	17:34	17:41	17:50	18:00
		16:47	16:54	17:05	17:15	17:20		17:31				17:16	17:21	17:31	17:42	17:49		18:02
	16:45	16:54	17:01	17:12	17:22	17:27	17:35	17:45			17:15	17:23	17:28	17:38	17:49	17:56	18:05	18:15
		17:02	17:09	17:20	17:30	17:35		17:46				17:31	17:36	17:46	17:57	18:04		18:15
	17:00	17:09	17:16	17:27	17:37	17:42	17:50	18:00			17:30	17:38	17:43	17:53	18:04	18:11	18:20	18:30
		17:17	17:24	17:35	17:45	17:50		18:01				17:46	17:51	18:01	18:12	18:19		18:31
	17:15	17:24	17:31	17:42	17:52	17:57	18:05	18:15			17:45	17:53	17:58	18:08	18:19	18:26	18:35	18:45
		17:32	17:39	17:50	18:00	18:05		18:16				18:01	18:06	18:16	18:27	18:34		18:46
	17:30	17:39	17:46	17:57	18:07	18:12	18:20	18:30			18:00	18:08	18:13	18:23	18:34	18:41	18:50	19:00
		17:47	17:54	18:05	18:15	18:20		18:30				18:16	18:21	18:31	18:42	18:49		19:01
	17:45	17:54	18:01	18:12	18:22	18:27	18:35	18:45			18:15	18:23	18:28	18:38	18:49	18:56	19:05	19:15
		18:02	18:09	18:20	18:30	18:35		18:45				18:30	18:35	18:45	18:56	19:03	19:12	
	18:00	18:09	18:16	18:27	18:37	18:42	18:50	19:00			18:30	18:37	18:42	18:51	19:02	19:09	19:17	19:30
		18:15	18:22	18:33	18:43	18:48		19:00				18:45	18:50	18:59	19:10	19:16	19:24	
	18:15	18:23	18:29	18:40	18:49	18:54	19:01	19:15			18:45	18:52	18:57	19:06	19:17	19:23	19:31	19:45
		18:31	18:37	18:48	18:57	19:02						19:00	19:05	19:14	19:25	19:31	19:39	
	18:30	18:38	18:44	18:55	19:04	19:09	19:16	19:30			19:00	19:07	19:12	19:21	19:32	19:38	19:46	20:00
		18:46	18:52	19:03	19:12	19:17					19:15	19:22	19:27	19:36	19:47	19:53	20:01	20:15
	18:45	18:53	18:59	19:10	19:19	19:24	19:31	19:45			19:30	19:37	19:42	19:51	20:02	20:08	20:16	20:30
		19:01	19:07	19:18	19:27	19:32					19:45	19:52	19:57	20:06	20:17	20:23	20:31	20:45
	19:00	19:08	19:14	19:25	19:34	19:39	19:46	20:00			20:00	20:07	20:12	20:21	20:32	20:38	20:46	21:00
	19:15	19:23	19:29	19:40	19:49	19:54	20:01	20:15			20:15	20:22	20:27	20:36	20:47	20:53	21:01	21:15
	19:30	19:38	19:44	19:55	20:04	20:09	20:16	20:30			20:30	20:37	20:42	20:51	21:02	21:08	21:16	21:30
	19:45	19:53	19:59	20:10	20:19	20:24	20:31	20:45			20:45	20:52	20:57	21:06	21:17	21:23	21:31	21:45
	20:00	20:08	20:14	20:25	20:34	20:39	20:46	21:00			21:00	21:07	21:12	21:21	21:32	21:38	21:46	22:00
	20:15	20:23	20:29	20:40	20:49	20:54	21:01	21:15			21:15	21:22	21:27	21:36	21:47	21:53	22:01	22:15
	20:30	20:38	20:44	20:55	21:04	21:09	21:16	21:30			21:30	21:37	21:42	21:51	22:02	22:08	22:16	22:30
	20:45	20:53	20:59	21:10	21:19	21:24	21:31	21:45			21:45	21:52	21:57	22:06	22:17	22:23	22:31	22:45
	21:00	21:08	21:14	21:25	21:34	21:39	21:46	22:00			22:00	22:07	22:12	22:21	22:32	22:38	22:46	23:00
	21:15	21:23	21:29	21:40	21:49	21:54	22:01	22:15			22:15	22:22	22:27	22:36	22:47	22:53	23:01	
	21:30	21:38	21:44	21:55	22:04	22:09	22:16	22:30			22:30	22:37	22:42	22:51	23:02	23:08	23:16	23:30
	21:45	21:53	21:59	22:10	22:19	22:24	22:31	22:45			22:45	22:52	22:57	23:06	23:17	23:23	23:31	
	22:00	22:08	22:14	22:25	22:34	22:39	22:46	23:00			23:00	23:07	23:12	23:21	23:32	23:38	23:46	0:00
	22:15	22:23	22:29	22:40	22:49	22:54	23:01	23:05			23:05	23:12						
	22:30	22:38	22:44	22:55	23:04	23:09	23:16	23:30			23:30	23:37	23:42	23:51	0:02	0:08	0:16	
	22:45	22:53	22:59	23:10	23:19	23:24	23:31	23:35			23:35	23:42						
	23:00	23:08	23:14	23:25	23:34	23:39	23:46	0:00			0:00	0:07	0:12	0:21	0:32	0:38	0:46	
	23:30	23:38	23:44	23:55	0:04	0:09	0:16	0:20			0:20	0:27						
	0:00	0:08	0:14	0:25	0:34	0:39	0:46	0:50			0:50	0:57						

Blocking a Rail Schedule

Now we will see some differences from what we learned when blocking a bus schedule. Study the example and note that we have already preliminarily blocked the trips by assigning a leaving time for the next trip on each side of the Schedule Sheet. In this way, we make it easier to assign block numbers to the trips and also to see where each block begins and ends. We could also use this as a visual cue to do some **block straightening** if we wanted to. One of the main reasons for manipulating finished blocks on rail schedules such as this is not the runcut, but in balancing the two yards. We will tackle that once we finish blocking.

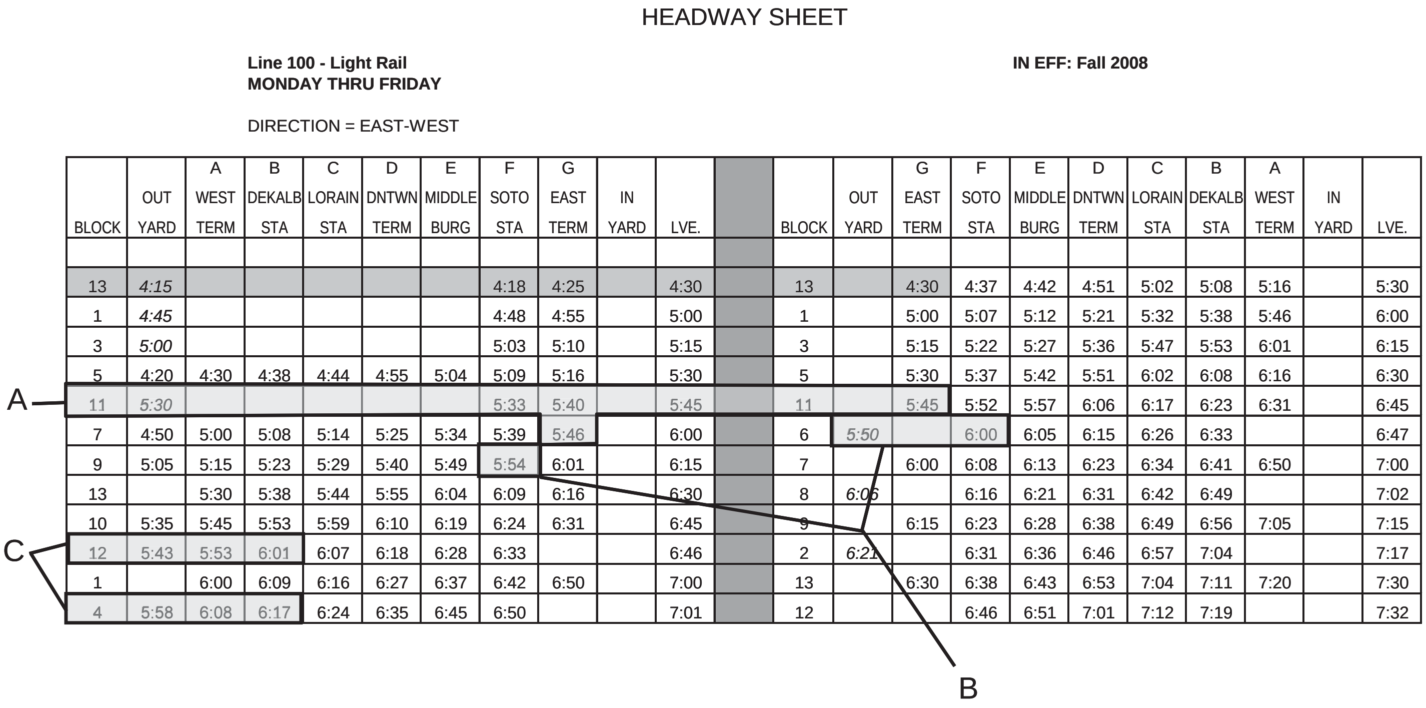
We start blocking the schedule by looking for the start and end points of the block (where there is no earlier or later trip hooking to our trip). Remember that the West Yard is near the West Terminal. We can assign a pull-out time to the first scheduled time on the block which will be sufficient for the train to make its way out of the yard, reverse if necessary (hopefully not necessary if the design engineers have done their job), and pull into the platform of the station. If the yard is beyond the end of the line, the train can pull straight in and be ready to leave on the scheduled time. In this case, the yard is just east of the West Terminal station, so the pull-out time must include time sufficient to pull up to the platform and reverse direction. This is where a thorough knowledge of the light rail system and its operation is vital. In the example, we have allowed 10 minutes, which our operating personnel have told us is sufficient.

The yard at the east end is at Soto Station, seven minutes from the East Terminal. We want to keep track of trains going into and out of service, so rather than giving the train a pull-out time from the yard and just letting it appear at East Terminal before its leaving time on its first trip westbound, we establish a short pull-out trip on the schedule so we have better control of train movements. The 4:30 AM westbound trip is an example. In building the pull-out trip, we allow a few minutes for layover, which is actually time to turn the train and accommodate boarding passengers. Five minutes is sufficient for this. We back up from the five-minute layover to establish a time at Soto Station and then apply a pull-out time to it. From the East Yard to Soto is only three minutes.

The short pull-out trip is highlighted in gray in the following figure. Other pull-out issues are also referenced by callouts A through C, and are discussed in the following paragraphs.

block straightening

The procedure of looking at blocks once the blocking process is finished and rehooking block beginnings or ends to yield blocks that will be more efficient in the runcut process. For instance, a block that is 14 hours long might be extended by swapping next trips with another block to extend to 16 hours, which would offer a better runcutting potential.



HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

DIRECTION = EAST-WEST

BLOCK	OUT YARD	A WEST TERM	B DEKALB STA	C LORAIN STA	D DNTWN TERM	E MIDDLE BURG	F SOTO STA	G EAST TERM	IN YARD	LVE.		BLOCK	OUT YARD	G EAST TERM	F SOTO STA	E MIDDLE BURG	D DNTWN TERM	C LORAIN STA	B DEKALB STA	A WEST TERM	IN YARD	LVE.
13	*4:15*						4:18	4:25		4:30		13		4:30	4:37	4:42	4:51	5:02	5:08	5:16		5:30
1	*4:45*						4:48	4:55		5:00		1		5:00	5:07	5:12	5:21	5:32	5:38	5:46		6:00
3	*5:00*						5:03	5:10		5:15		3		5:15	5:22	5:27	5:36	5:47	5:53	6:01		6:15
5	4:20	4:30	4:38	4:44	4:55	5:04	5:09	5:16		5:30		5		5:30	5:37	5:42	5:51	6:02	6:08	6:16		6:30
11	*5:30*						5:33	5:40		5:45		11		5:45	5:52	5:57	6:06	6:17	6:23	6:31		6:45
7	4:50	5:00	5:08	5:14	5:25	5:34	5:39	5:46		6:00		6	*5:50*		6:00	6:05	6:15	6:26	6:33			6:47
9	5:05	5:15	5:23	5:29	5:40	5:49	5:54	6:01		6:15		7		6:00	6:08	6:13	6:23	6:34	6:41	6:50		7:00
13		5:30	5:38	5:44	5:55	6:04	6:09	6:16		6:30		8	*6:06*		6:16	6:21	6:31	6:42	6:49			7:02
10	5:35	5:45	5:53	5:59	6:10	6:19	6:24	6:31		6:45		9		6:15	6:23	6:28	6:38	6:49	6:56	7:05		7:15
12	5:43	5:53	6:01	6:07	6:18	6:28	6:33			6:46		2	*6:21*		6:31	6:36	6:46	6:57	7:04			7:17
1		6:00	6:09	6:16	6:27	6:37	6:42	6:50		7:00		13		6:30	6:38	6:43	6:53	7:04	7:11	7:20		7:30
4	5:58	6:08	6:17	6:24	6:35	6:45	6:50			7:01		12			6:46	6:51	7:01	7:12	7:19			7:32

Continue to build short trips for the rest of the pull-outs to East Terminal using this same principle. For later pull-outs, you have to be aware of mainline trips also heading east. Block 11 pulls out to handle the 5:45 AM trip westbound (see callout A above). But there is a long line trip due to arrive at East at 5:46 AM one minute later. You must ensure that the pull-out trip is sufficiently early that it doesn't get in the way of the through trip and still allows sufficient layover. In this case, we have it arrive at 5:40 AM, six minutes earlier than the through eastbound trip, which also allows it five minutes on the platform to change ends and board passengers. Similar thinking will be used throughout the day for pull-out and pull-in trips.

Pull-outs for the short trips on the east end can just pull up to the platform, change ends, and be prepared to leave on time. We allow 10 minutes for this, which is time to clear the yard, change ends, and receive passengers on the platform. We need to make sure we do not interfere with the previous westbound trip. For example, the first short trip pull-out is block 6 at 5:50 AM. It is due to leave Soto Station at 6:00 AM (see callout B above). However, the trip before it is a long line train due to leave Soto at 5:52 (see Block 11 above). The train operator has to clear that train and if the eastbound track is to be used, also clear a 5:54 eastbound before arriving at the platform, preferably five minutes before the scheduled leaving time.

On the west end, it makes sense to pull out of West Yard to West Terminal and begin service there. We take these short trips and extend them backward one time point. This is shown on callout C in the above example. We make the same adjustment in reverse for pull-ins. When calculating mileage, the scheduler needs to keep in mind these "half-long" trips will have a different pattern and mileage. These kinds of decisions show you the nuances of difference you face in doing rail scheduling.

We should note that the East Yard trains' pull-out and pull-in times on the Schedule Sheet are shown in italic. That will help us later when we resolve the yard count. We did not make a distinction in the block numbering in this case. We could have, numbering all East Yard blocks from, say, 51 up. The numbering used on the blocks is standard to the way described in earlier chapters. We put the all day blocks in order at the start of the base period (they don't stay in order because of the shorter cycle of the short trips), then number the four AM blocks above these, then the four PM blocks. So we ultimately have blocks numbered from 1 to 18.

Yard Balancing

We build our Train Block Summary in the spreadsheet, just as we did in the bus example. In this case, the East Yard pull-outs and pull-ins are shaded so they are easy to count. Some prior planning and a largely symmetrical schedule have given us the same number of final pull-ins to each yard as we had pull-outs at the start. In fact, the number of trains from each yard is the same—nine. If we had an imbalance, we would have to establish one or more trips to rectify the situation. These yard balancing trips could be in service or deadhead, before or after service hours. In any event, such trips are wasteful, using mileage and hours that do not benefit the rider. If such trips are needed, it is better to schedule the trip at a time when it can be in-service. The least intrusive way would be to extend an existing pull-in trip across the route to the other yard.

TRAIN BLOCK SUMMARY								
		OUT		IN		VEH.		VEH.
TRAIN		TIME		TIME		HOURS		MILES
1		4:45		1:02		20:17		
2		6:21		19:22		13:01		
3		5:00		23:17		18:17		
4		5:58		19:37		13:39		
5		4:20		23:47		19:27		
6		5:50		19:34		13:44		
7		4:50		0:56		20:06		
8		6:06		19:49		13:43		
9		5:05		23:11		18:06		
10		5:35		23:41		18:06		
11		5:30		9:53		4:23		
12		5:43		9:40		3:57		
13		4:15		9:30		5:15		
14		6:13		9:38		3:25		
15		15:12		24:26		9:14		
16		15:13		19:07		3:54		
17		15:20		24:42		9:22		
18		15:21		19:22		4:01		
TOTAL						211:57		

As an example, if we needed one more pull-in to the West Yard, we might consider taking block 3, scheduled on a short pull-in trip leaving East Terminal at 11:05 PM (highlighted below in gray), and extending it to West Terminal. We would make it the 11:15 PM trip, which would effectively extend the 15-minute service one interval later westbound. It would add platform time to be sure, but it would do some useful work for the time. It is better still to plan the headway and transition times, as we have throughout this schedule, to eliminate yard balancing trips entirely whenever possible.

HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

DIRECTION = EAST-WEST

BLOCK	NO. CARS	RUN	OUT YARD	A WEST TERM	B DEKALB STA	C LORAIN STA	D DNTWN TERM	E MIDDLE BURG	F SOTO STA	G EAST TERM	IN YARD	LVE.		BLOCK	NO. CARS	RUN	OUT YARD	G EAST TERM	F SOTO STA	E MIDDLE BURG	D DNTWN TERM	C LORAIN STA	B DEKALB STA	A WEST TERM	IN YARD	LVE.
1	1			22:00	22:08	22:14	22:25	22:34	22:39	22:46		23:00		1	1			23:00	23:07	23:12	23:21	23:32	23:38	23:46		0:00
3	1			22:15	22:23	22:29	22:40	22:49	22:54	23:01		23:05		3	1			23:05	23:12						*23:17*	
15	1			22:30	22:38	22:44	22:55	23:04	23:09	23:16		23:30		15	1			23:30	23:37	23:42	23:51	0:02	0:08	0:16	0:26	

Note that we were primarily concerned with checking the balance of early pull-outs against final pull-ins. But imbalances can also occur from AM Peak pull-ins at each yard that are not equal to PM pull-outs from those same yards. Our symmetrical schedule assured equal pull-ins to pull-outs in the midday, but if the number had not been equal, we could rectify it either by adding a trip in the midday or at the end of the day. In other words, the between-peaks counts do not have to be equal, but the difference still has to be made up somewhere in the schedule. The rule of thumb is: total pull-outs from each yard must equal total pull-ins. The scheduler who pays attention to this rule wins friends and credibility among the operating ranks.

One more comment on this topic: yard balancing has implications for our eventual runcut. Even though our yard count balances for this schedule, no less than 10 of the 18 trains pull out of one yard and pull in to the other. To assure that all blocks returned to their place of origin would, in this case, require at least 10 more one-way trips, which we have already decided would be unproductive. We have a number of cheaper ways of taking care of crews returning to the wrong yard within the runcut. We can deadhead crews cheaper than we can trains. We can also swap crews from two "off yard" trains at some point before the end of their runs. Finally, we may have the ability within our work rules to terminate crews at one yard and bring them back on after a split at the other.

Adding and Cutting Cars

Looking again at our sample schedule, we note that a column has been added for train make-up, the number of cars that make up the train for each trip. This number can change quite a bit during the day. Standard practice on light rail systems is to operate two-car trains during base periods. Some systems add one or two more cars during peaks. Usually evening and night service is handled by single cars. Our system follows this practice, although we do not add cars for the peaks just to keep the example schedule from becoming too complicated.

Although there are transit systems where consist length is handled as transit board policy, for the most part it is the scheduler, along with his/her manager/supervisor, who decides the number of cars that will be required as he/she has the traffic check information available in order to make a knowledgeable decision on how many cars will be required at max load points in order to meet the system standards for loadings. One reason for constructing light rail lines is their large passenger carrying capacity. A standard articulated light rail car which is 90-95 feet in length can seat 70 per car and carry another 60 standees comfortably. Multiply this by a three-car train, and you have the capability of transporting almost 400 people on a single trip and with the economy of only one operating crew member—the train operator. It would take at least six regular buses to provide the same capacity.

However, there is a significant expense in carrying around cars that are not needed to meet load requirements.[3] So the scheduler should be expected to create an Add and Cut list in conjunction with the schedule to assure that proper vehicle utilization takes place.

For our schedule, we note that all blocks pull out with two cars. This can be set up by yard crews and be ready for the train operators. Nothing here needs to be scheduled, other than the pull-out itself. Since we are not adding or cutting for the peaks, the first time the train consists change is after the PM peak and the beginning of the evening service. Our short trip blocks can pull in as two-car trains, as can some of the full trip blocks. Again, the scheduler does not need to include these as cuts. The blocks which stay out all lose their second cars beginning with the 19:00 departures from both terminals (shown below). The exact movement for getting these second cars back to the yard is usually worked out by the Light Rail Operations people. They may cut incoming trains and accumulate cars up to a maximum number which they can ferry to the yard. All the scheduler needs to do it is to note the cut on the schedule.

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[3] Rail cars consume significant amounts of electricity simply "rolling along the rails." Further, as preventative maintenance is done on an accumulated mileage basis, having excess cars in a train will trigger more inspections than are truly warranted. The cost-savings of reducing excess car miles by repeated adds and cuts is often offset by the necessity to staff yards with "switching" crews (switching cars onto and off trains). It could well be less expensive to operate excess car miles rather than add additional staff at the yards. This is a detailed trade-off analysis that often falls to the scheduler to perform.

HEADWAY SHEET

Line 100 - Light Rail
MONDAY THRU FRIDAY

IN EFF: Fall 2008

DIRECTION = EAST-WEST

BLOCK	NO. CARS	OUT YARD	A WEST TERM	B DEKALB STA	C LORAIN STA	D DNTWN TERM	E MIDDLE BURG	F SOTO STA	G EAST TERM	IN YARD	LVE.		BLOCK	NO. CARS	OUT YARD	G EAST TERM	F SOTO STA	E MIDDLE BURG	D DNTWN TERM	C LORAIN STA	B DEKALB STA	A WEST TERM	IN YARD	LVE.
3	2		18:15	18:23	18:29	18:40	18:49	18:54	19:01		19:15		10	2		18:45	18:52	18:57	19:06	19:17	19:23	19:31		19:45
16	2			18:31	18:37	18:48	18:57	19:02		*19:07*			8	2			19:00	19:05	19:14	19:25	19:31	19:39	19:49	
15	2		18:30	18:38	18:44	18:55	19:04	19:09	19:16		19:30		1	1		19:00	19:07	19:12	19:21	19:32	19:38	19:46		20:00
2	2			18:46	18:52	19:03	19:12	19:17		*19:22*			3	1		19:15	19:22	19:27	19:36	19:47	19:53	20:01		20:15
5	2		18:45	18:53	18:59	19:10	19:19	19:24	19:31		19:45		15	1		19:30	19:37	19:42	19:51	20:02	20:08	20:16		20:30
4	2			19:01	19:07	19:18	19:27	19:32		*19:37*			5	1		19:45	19:52	19:57	20:06	20:17	20:23	20:31		20:45
7	1		19:00	19:08	19:14	19:25	19:34	19:39	19:46		20:00		7	1		20:00	20:07	20:12	20:21	20:32	20:38	20:46		21:00
9	1		19:15	19:23	19:29	19:40	19:49	19:54	20:01		20:15		9	1		20:15	20:22	20:27	20:36	20:47	20:53	21:01		21:15
17	1		19:30	19:38	19:44	19:55	20:04	20:09	20:16		20:30		17	1		20:30	20:37	20:42	20:51	21:02	21:08	21:16		21:30
10	1		19:45	19:53	19:59	20:10	20:19	20:24	20:31		20:45		10	1		20:45	20:52	20:57	21:06	21:17	21:23	21:31		21:45
1	1		20:00	20:08	20:14	20:25	20:34	20:39	20:46		21:00		1	1		21:00	21:07	21:12	21:21	21:32	21:38	21:46		22:00
3	1		20:15	20:23	20:29	20:40	20:49	20:54	21:01		21:15		3	1		21:15	21:22	21:27	21:36	21:47	21:53	22:01		22:15

The Add and Cut list is arranged as a table at the bottom of the schedule. There are columns for pulling out and in between the peaks as well as the columns for the initial AM pull-outs and late PM pull-ins. Most of the table for this schedule just shows blocks as OUT or IN, reflecting that the yard has set up the train size and nothing changes on the road. In the Last column you see times when each block is due to have its second car cut. The list is divided between the two cut points...each end terminal. This time listing is invaluable for the operating personnel who must assign employees to either cut the second cars or assist the train operators who do the cutting.

ADDS AND CUTS

TRAIN	AM ADD	AM CUT	PM ADD	PM CUT
AT WEST TERMINAL				
7	OUT			18:50
9	OUT			19:05
17			OUT	19:17
10	OUT			19:31
AT EAST TERMINAL				
1	OUT			18:50
3	OUT			19:01
15			OUT	19:16
5	OUT			19:31

One aspect of adding and cutting that will affect the scheduler is the availability of employees to do the actual work. The policy of the particular light rail system may be to use yard crews. If so, many systems schedule these crews as Miscellaneous Runs. Yard work is often included as pieces within regular train operator runs. The need is to schedule crews so they are on hand for tasks such as cutting and adding while still having yard crews available for the yard.

Besides the Add and Cut sheet, the scheduler will add a second mileage column to the Block Summary table to account for the mileage of the second car of each train. If additional cars are regularly used, a third and even a fourth car mileage column is added. Mileage for these cars can be calculated in the same manner as for the primary car—but placing a count for each trip and pull-out/pull-in pattern in the mileage table. We are usually not concerned about the vehicle hours of the extra blocks, as they will not have crews assigned to them and so are not part of the vehicle hours of the schedule. If Operations or Maintenance rely on operating hours for costs or for scheduling inspections, then the hours may need to be accumulated for the cars as well, but these hours should not be mixed into the primary Vehicle or Platform Hour calculation for the schedule.

Scheduling of Yard Staff

As discussed above, operating personnel are required to staff yards; they hostle equipment into and out of shop buildings, switch cars onto and off of trains (adding and cutting), bring equipment to terminal platforms, etc.

Unlike "runs," this work is scheduled more typically like nontransportation jobs, e.g., police officers. That is: in transportation, the scheduler has prepared two sets of schedules, one for the equipment and then one for the personnel to operate the equipment. In nontransportation work, only personnel are scheduled. Because it is not mated to an equipment schedule it is scheduled to the need for staff presence, not equipment operation. The determination of staffing levels is based on the needs of the operating departments—Transportation and Maintenance. Typically, after Maintenance identifies their needs to Transportation, the Transportation Department will combine them with their internal needs and ask Schedulers to include them for posting/picking, i.e., the "Miscellaneous Runs" mentioned above. Sometimes they will be rostered separately (if the yard jobs are their own job class); sometimes not only are the rosters comingled with the "road" (revenue) jobs on pick sheets, but some individual jobs are a combination of road and yard work as previously discussed. But quite often, yard staffing work is not part of the vehicle blocking/run cutting process. Indeed, at some systems, the Schedules department isn't even involved in the scheduling and posting of yard work.

Heavy Rail Scheduling

Since we used a typical light rail scheduling exercise, it would be of interest to contrast it with a typical heavy rail (subway or elevated) schedule. As mentioned earlier, heavy rail systems always have the benefit of being completely separated from other traffic (there are a couple of exceptions, but those really prove the rule).

Here are some differences in heavy rail scheduling:

- Running times would vary only slightly throughout the day. What changes there are would reflect (1) increased dwell time at stations because of the increased passenger activity and (2) potentially heavy train traffic, especially if headways are below three minutes.
- Longer trains are generally run. The average heavy rail train is four to six cars. The schedule usually tracks the consists as they change, but adding and cutting cars is more the role of the operating personnel and not usually tracked on the schedule.
- Closer headways at most times of the day than found on typical light rail lines. Heavy rail generally is a mode chosen for its greatly increased passenger carrying capacity, and this is reflected in the schedule.
- On some systems where lines merge and diverge, extra care must be taken to assure the spacing of trains along common portions of routes. Sometimes several lines must be scheduled together because of the interplay between them. Typically, heavy rail schedules take much more time to build because of these factors, regardless of whether the scheduler builds them by hand or by computer.
- Heavy rail systems favor doing crew drop-back at terminals. This is because the platform capacity and the short headways dictate a quick turnaround of equipment, which would not provide adequate layover for crews. It is not unusual for runs on heavy rail to be multiple-piece runs, with each piece working only one trip on each vehicle.
- Although the trend has been to go to one-person operation over the last 20 years, there are still heavy rail systems which use conductors. Conductor runs generally follow that of the train operator, but not always. This can add that much more complication to constructing the schedule. In some cases, the conductor has different allowances from the train operator.
- Heavy rail schedules tend to change less frequently than light rail schedules. However, normal maintenance and construction often requires highly detailed alternate schedules to account for single tracking, line cutbacks, bypassing stations, and other methods of freeing track segments for maintenance. These usually occur on weekends.

Schedulers are challenged to rewrite the service to accommodate the maintenance while returning the service to normal for the Monday morning rush hour.

Terminal Design and Scheduling Efficiency

As discussed at the beginning of this chapter, one difference between rail and bus scheduling is the potential for a scheduler to provide vital input to the planners and engineers designing the layout/trackwork for a new or rebuilt rail terminal. The closest bus counterpart is when a major transit center with expansive facilities is about to be constructed.

There are lines that simply terminate at a platform in a one (single) track configuration (Diagram 1). The side track in Diagram 1 goes to the yard. This arrangement is most commonly used on lines with wide headways that will remain wide for the foreseeable future.

But for the most part—and the model used for the scheduling examples in this chapter—rail terminals are center (sometimes called island) platforms with a track on each side and a cross-over "in-front" of the station (Diagram 2).

These have their limitations, notably capacity in terms of headways and passenger convenience. When things go off-schedule, particularly in the PM rush, trains will accumulate waiting to get into the terminal station. On-board passengers are quite anxious; not only are they already late, but they are invariably standing, crowding near doors, hoping to make a dash exit to their connecting bus—which itself may be on a 30-minute or longer headway. They don't want to suffer through a missed connection.

Diagram 3 is a schematic track layout of a rail terminal that in application can provide for tight intervals, good delay management as well as minimum train [time] movement/reduced train and crew count.

Use of cross-over A—which should be as close to the platform as possible in order to minimize the effective single track length—is the same in Diagrams 1, 2, and 3.

If the terminal is built along the lines of Diagram 3, use of crossover B is preferred, provided that the increment of length/running time it adds does not require an additional consist and/or crew in the cycle. This provides customers the fastest ride from the prior station into the terminal with little, if any, delay. This is because the train can approach the terminal at normal station arrival speed on tangent track and does not need to slow down to cross over.[4]

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[4] For Diagram 2 and for Diagram 3 when crossover A is used, when both tracks at the terminal are empty, the inbound track is the preferred arrival track so that, if need be, when it departs an arriving train need not be "held out" and can, coincidentally, arrive on the other track without delay.

Diagram 1

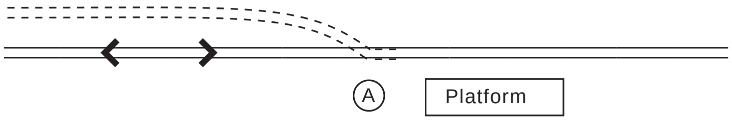

Diagram 2

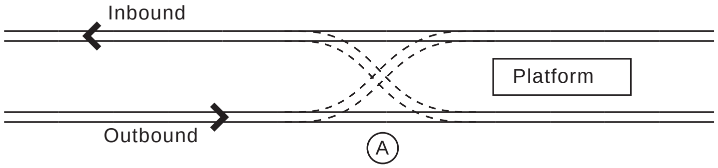

Diagram 3

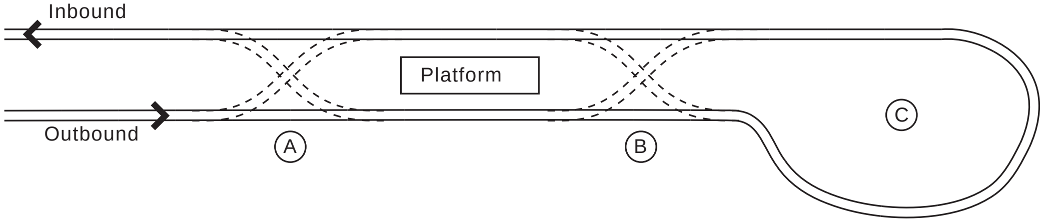

Diagram 3 particularly works well in schedules where there are drop-back crews. When the train does arrive, the drop-back crew will board at the rear of the train, "ride" into the "pocket" and reverse the train's direction with the original crew alighting when the train gets back into the platform.

Use of loop C, again if it does not require an additional consist and/or crew in the cycle, is operationally superior but more costly in terms of accumulated car miles. Much of this, of course, will depend on the actual length and radius of the loop.

The reason for this superiority in service delivery is because the train's motion is one that is continuous; the terminal is nothing more than another station to be stopped at. Critically, when properly operated, passengers are on board trains that are not held out of the station (it is important in looping operations that crew reliefs/drop-backs be done on the inbound/departure track). This is particularly important on lines where tight headways are operated for sustained periods (20-30 minutes or longer). In fact, in such cases, there is merit to a design where there is space on the loop for trains to accumulate, getting off the mainline and "out-of-the-way" in the peak. In off-peak periods crossover B can be used, and during periods of wide intervals, even A.

There are, of course, permutations and various combinations, which are dependent on land availability and associated cost factors. It is highly desirable if Diagram 2 is selected to have tail tracks with a crossover behind the station in addition to the basic design. This is so both a pull-back operation (the preferred operating method in Diagram 3) can be used in peak periods on the tail tracks as well as off-peak storage of out of service cars/consists, minimizing car-miles.

Knowledge of the impact of these designs on scheduling is imperative. As a scheduler, you want to bring to the table recommendations for the least-cost, most-flexible, and most-passenger-friendly design appropriate.

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Glossary

Glossary

Agency-developed rostering is the process in which the transit agency packages daily runs into weekly work schedules or rosters in advance of the sign-up. The operators then select from the prepared rosters.

Alternate-fuel buses are buses using low-polluting fuels in place of diesel or gasoline. Examples of alternate fuels include compressed natural gas (CNG), liquefied natural gas (LNG), ethanol, methanol, and propane. Electric or hybrid electric vehicles also fall within this definition.

AM block is a block that is in service only during the AM peak period.

AM peak period is the period in the morning when the greatest level of service is provided, typically 6 to 9 AM.

Articulated bus is an extra-long (54 to 62 feet) bus with the rear body section connected to the main body by a joint mechanism which allows the vehicle to bend when in operation for sharp turns and curves and yet have a continuous interior for passenger movement.

Automatic Passenger Counting (APC) systems count the number of boardings and alightings at each stop while also noting time, location, and direction. Infrared beams are the most common means used in counting. Stop location is identified through the use of data sources such as global positioning systems (GPS), signpost emitters, GIS maps, odometer readings, and inertial navigation. Data from all these sources must be extensively compiled (from multiple buses/trips on a route) and processed, either by an on-board computer or centrally, to be meaningful.

Automatic Vehicle Location (AVL) systems are vehicle tracking systems that function by measuring the real-time position of each vehicle and relaying this information back to a central location. The vehicle location is identified through the use of global positioning systems (GPS). The information is used to assist transit dispatchers as well as inform travelers of bus status. AVL is a potential source of running time and on time performance data for scheduling, but only if an archival reporting system is included.

Average weekday is a representative weekday in the operation of the transit system computed as the mathematical average of data for several typical weekdays. A typical weekday is one where there are no anomalies such as high ridership due to extra service added for a special event or low ridership due to inclement weather. Some schedulers claim that this does not really exist. Average Saturday and average Sunday are determined in the same way.

Banging out the schedule is a rail scheduling term for the process of scheduling trips on lines that share a common segment in such a way that spaces the trains on the common segment or eliminates conflicts with two trains running too close together. If the spaces on the common segment are evenly apart this is the rail equivalent of "intertiming."

Barn – see **garage**

Base – see **garage**

Base block is a block that is in service during the AM peak, midday, the PM peak and possibly the evening periods. Straight runs are often cut from base blocks.

Base period includes the hours between the AM and PM peak periods, during which ridership is generally lower than in peak periods. Also known as "midday" or "off-peak period."

Base vehicles are the number of vehicles required to operate the route at the required headway during the base period. Quickly calculated as: cycle time in the base period divided by headway in the base period. Also referred to as "base period vehicle requirement."

Bid – see **sign-up**

Bid package – see **rostering**

Bid sheet – see **run guide**

Block is a vehicle (or train) assignment that includes the series of trips operated by each vehicle from the time it pulls out to the time it pulls in. A complete block includes a pull-out trip from the garage followed by one or (usually) more revenue trips and concluding with a pull-in trip back to the garage. Also known as "coach" or "train."

Block graph is a graphical representation of all blocks assigned to a garage that must be considered in the runcut solution. The graph includes, at a minimum, the start and end times of each block, and may also include terminal times and all eligible relief times. Understanding the number and duration of all blocks is an important requisite in reaching an optimal runcut solution.

Block number is a unique number associated with a specific block, used to track the block throughout the scheduling process and as a means of identification for the operations department.

Block straightening is the procedure of looking at blocks once the blocking process is finished and rehooking block beginnings or ends to yield blocks that will be more efficient in the runcut process. For instance, a block that is 14 hours long might be extended by swapping next trips with another block to extend to 16 hours, which would offer a better runcutting potential.

Block summary table provides a summary of vehicle statistics, including platform hours and mileage, by block.

Blocking is the process in which trips are "hooked" together to form a vehicle assignment or block.

Blocking sheet is a sheet listing all blocks that also includes the trips and times for all trips within each block.

Board – see **paddle** or **extraboard**

Bonus time – see **make-up time**

Boost time – see **make-up time**

Branch is one of two or more outer route segments served by a single route.

Bus hours – see **vehicle hours**

Bus Rapid Transit (BRT) is a form of bus service that, through improvements to infrastructure, vehicles and scheduling, is intended to enhance service quality compared to an ordinary bus line. Features may include exclusive right-of-way, signal priority, widely spaced stops, higher capacity vehicles with special branding, stations, headway-based schedules, and off-bus fare collection.

Cafeteria-style rostering is the process in which operators create their own rosters by selecting daily runs and days off from a master list.

Car hours – see **vehicle hours**

Car pooling is the use of an automobile to ferry more than one operator between the garage and a relief location, or even between two relief locations.

Check-out time – see **clear allowance**

Clear allowance is the amount of time paid to an operator at the conclusion of the run to turn in transfers, fare media, or other supplies and reports. Also known as "turn-in allowance" and "check out time."

Coach – see **block**

Collaterals include all of the various types of penalties and premiums that might be required to make legal runs.

Comments – see **note**

Consist *(pronounced CON-sist)* is a rail term that refers collectively to the rail cars comprising a train, i.e., a four-car train is a four-car consist.

Crew block is the series of trips operated by each train crew from pull-out to pull-in. The crew block will differ from the train block if drop-backs are scheduled for the crews.

Cycle time equals the round trip running time plus layover time. This is also known as "round-trip cycle time" or "round-trip time."

Deadhead is the time and distance that a bus needs to travel in places where it will not pick up passengers. Deadheading is typically required to get buses to and from their garage, or when bus operators need to travel from one route or point to another during their scheduled work day. Also known as "non-revenue travel."

Deadhead hours include pull-in time, pull-out time, and deadhead time from one route or point to another.

Deadhead miles include pull-in mileage, pull-out mileage, and deadhead mileage from one route or point to another.

Depot – see **garage**

Dispatch sheet is a list of all runs or blocks sorted by start time, typically used by operations to track staff and vehicle movements throughout the day.

District – see **garage**

Division – see **garage.** Division may represent a group of garages with some common labor and/or management organization.

Dovetailing – see **intertiming**

Drop-back is a technique where the operator or train crew gets off an arriving vehicle at a terminal, takes layover, and assumes operation of the next vehicle to arrive. Most common on frequent rail lines where close headways do not allow sufficient layover time for the train crew, this technique is also used for special events to maximize the number of trains in service. If service is very frequent, the train crew may not board the next train but instead the train after that; this is called a "double drop-back." Some agencies use the term "fall-back" instead.

End of the line (EOL) – see **terminal**

Exception scheduling is scheduling activity undertaken to address major construction detours or delays, sporting events, holiday service, or other special situations.

Express service is a service generally connecting residential areas with activity centers via a high-speed, non-stop route with limited stops at each end for collection and distribution. Park-and-ride lots are a common feature of express service at the residential end of the route. Similar to limited-stop service, but with a long non-stop segment.

Extraboard is a group of operators who provide coverage of vacant runs and other work on a daily or weekly basis. Operators may pick the extraboard during a sign-up or may be assigned to the extraboard if no more runs are available. Also known as "the Board."

Fall-back – see **drop-back**

Fit-in point – see **pull-on location**

Free running time is the absence of a specified running time along a given segment, with an estimated arrival time at the end of the segment. Frequently used on the express portion of an express bus trip, free running time is a component of headway-based schedules and is sometimes included on the last segment of a local route.

Frequency is the number of vehicles passing a point on a route within a given unit of time, usually expressed as X vehicles per hour. See also "headway." Headway is the inverse of frequency: a frequency of six buses per hour is equivalent of a headway of 1/6 hour or 10 minutes.

Full-time operator is an operator available to work full-time runs and eligible to receive full benefits. A full-time operator is usually guaranteed 40 hours of work per week. Typically, full-time operators can select either a full-time run or a split run, or can choose to work on the extraboard.

Full-time run is a work assignment whose total hours equal or exceed the guaranteed minimum number of hours for a full-time operator. Also known as a "regular run."

Garage is the place where vehicles are stored and maintained and where operators report for their assignments. Also known as "barn," "base," "depot," "district," "division," "station," or "yard." See also "storage lot."

Garage relief is an operator relief that occurs at the garage.

Global Positioning System (GPS) is a satellite-based navigation system that provides accurate and continuous location information. Tunnels, terminals, and urban street canyons can limit GPS accuracy.

Guarantee time – see **make-up time**

Hawk – see **owl**

Headway is the interval of time between two vehicles running in the same direction on the same route, usually expressed in minutes. See also "frequency." Frequency is the inverse of headway: a headway of 10 minutes is equivalent to a frequency of one bus every ten minutes or six buses per hour. "Headway" is sometimes used by operations personnel to designate a gap in service or a missing bus.

Headway sheet is a document that displays all time points and trips on a route. Usually includes run numbers, block numbers, and pull-in and pull-out times. Used interchangeably in this manual with "master schedule," and also known as "recap" or "rotation."

Heavy rail is transit service using rail cars with self-contained, self-propelled motive capability, driven by electric power usually drawn from a third rail, operated on exclusive right-of-way with level platform boarding. Heavy rail generally utilizes longer trains and longer spacing between stations than Light Rail.

Hooking is the process of attaching the end of a trip in one direction to the beginning of a trip the other direction. A block is a series of hooked trips. Also see "rehooking" below.

Hot is a term used to describe a trip that leaves a time pointearly. Such a trip is "running hot."

Hub – see **transit center**

Inside time – see **swing time**

Interlining is the use of the same vehicle on a block operating on more than one route with the same operator, without returning to the garage during route changes. This is most often done at common terminals or for routes sharing a common trunk.

Interspersing - See **intertiming**

Intertiming is the process of scheduling trips of two or more routes that share a common segment in a manner that evenly spaces the trips over the common segment. Intertiming is intended to provide more frequent service for those passengers who begin and end their trips within the shared segment. Also known as "interspersing" and "dovetailing".

Intervening time – see **swing time**

Layover time is the time between the scheduled arrival and departure of a vehicle at a transit terminal. Often used interchangeably with "recovery time," although technically layover time is rest time for the operator between trips while recovery time is time built into the schedule to ensure an on-time departure for the next trip. In this manual, layover and recovery are calculated together, and the total time between trips is referred to as layover.

Light rail is a fixed-guideway mode of transit service using electrically propelled rail cars that draw current from overhead wires, operated on reserved but not necessarily grade-separated right-of-way. Light rail generally utilizes shorter trains (at times one-car trains) and shorter spacing between stations than heavy rail and may also operate in streets with mixed traffic.

Limited-stop service is a service typically operating on arterial streets that makes stops only at major points along the route. Similar to express service, but without a lengthy non-stop segment.

Line check – see **point check**

Line of work is a weekly work package, developed during rostering, that comprises a fixed set of runs and days off for a set workweek.

Line pick is a sign-up held in between scheduled sign-ups to fill one or more runs permanently vacated due to illness, disability, or termination. Only operators with less seniority than the prior holder of the vacated run are eligible to bid. Also, a special sign-up held on one route only due to a significant schedule change on the route during the sign-up period.

Line-up – see **sign-up**

Lines of work – see **rostering**

Loading standard is the agency-established goal for passenger loads (not the maximum vehicle load, which is considerably higher). The loading standard is usually expressed as a percentage of seated capacity, as the maximum number of standees, or as the maximum load. The loading standard often varies over the day, with peak-period loading standard higher than off-peak periods. Some agencies also specify a time or distance duration that certain loads are allowed (e.g., 150% for up to 10 minutes). The loading standard is used to calculate demand-based headways during the various periods of the service day.

Make-up time is time added to an operator's work hours to bring the total up to the guaranteed minimum (usually eight hours per day or 40 hours per week). Full-time operators often have an eight-hour guarantee, even if their runs are short of eight hours. Other terms include "guarantee time," "boost time," "bonus time," and "pad time."

Manifest – see **paddle**

Mark-up – see **sign-up**

Master run list is a list containing all weekday, Saturday, and Sunday runs. The Master Run List may be the Run Guide or some variation of the Run Guide. Typically used in cafeteria rostering.

Master schedule is a document that displays all time points and trips on a route. Usually includes run numbers, block numbers, and pull-in and pull-out times. Used interchangeably in this manual with "headway sheet," and also known as "recap" or "rotation."

Match-up sheet is a listing of all arrival and leave times of all routes at a particular terminal. This sheet simplifies the process of interlining trips.

Maximum load point is the location along the route where the passenger load is greatest. The maximum load point can differ by direction and by time of day. Long or complex routes may have multiple maximum load points, one for each segment. Also known as "peak load point."

Meet is when two trains, on two different tracks (in single-track operation, one train is on a passing siding), converge at the same location.

Midday period – see **base period**.

Miss – see **miss out**

Miss out is the term applied when a scheduled operator does not report on time for his/her assignment. Also known as "no show" or "miss."

Mode is a type of transit service characterized by vehicle or operational features. Common transit modes include motorbus, trolleybus, light rail, heavy rail, commuter rail, and demand-response.

Multipiece runs are runs made up of pieces from multiple blocks. In most cases, split runs are inherently multipiece runs. But either half of a split run could itself have multiple pieces, cut from multiple blocks.

Multipiece straight – see **straight run**

Node – see **transit center**

Non-revenue travel – see **deadhead**

No-show – see **miss out**

Note is text associated with a trip or a specific time pointon a trip. Typically reported on scheduling outputs such as headway sheets and paddles, it can be an essential part of posting information for the operator's pick. A subset of notes may also be exported to public timetables. Notes often describe exceptions, e.g., "trip does not operate when school is closed" or "trip departs from Gate X". Also known as "comments."

Off-peak period – see **base period**

On-board count – see **ride check**

On-board tally – see **ride check**

On-street relief is the process where, at a specific time during a specific trip on a block, one operator's run ends and another operator's run begins. The relief may occur at a terminal or at a designated point along the route (possibly close to the garage). On-street relief is used to minimize pull-out and pull-in miles and hours. Operators are usually paid travel time between the garage and the relief point. Reliefs may also occur at the garage; these are know as "garage reliefs."

On time is defined specifically by each system; a trip is considered on time if it arrives or departs from a time pointwithin a specified range of time. A typical range is 0 to 5 minutes after the scheduled arrival/departure time. A trip that leaves a time pointearly is referred to as "hot" or "running hot."

One-way trip – see **trip**

Open run is a run which was not bid at the previous sign-up or has been vacated during a sign-up due to retirements, terminations, long-term illnesses and such.

Outside time – see **spread time**

Overtime premium is pay at the rate of 1.5 times (or higher) the normal rate for work performed in excess of daily or weekly thresholds, usually eight or ten hours per day or 40 hours per week.

Owl is a run that operates during the late night/early morning hours to provide all-night service. Also known as "hawk."

Paddle is an output of the scheduling process that provides the operator with information regarding his or her workday—what time the work day starts/ends, how to get to/from relief locations, the trips to be operated, times at all timepoints, and notes. If an operator drives on more than one route in the day, the paddle will have all trips shown sequentially, as well as travel paths between routes if needed. The paddle may also include a list of route turns, route maps, farebox, headsign, and radio codes, and key intersections and stops that must be announced. Also known as "trip sheet," "board," "manifest," and "schedule."

Pad time – see **make-up time**

Paid relief – see **travel time**

Part-time operator is an operator who works less than 40 hours a week. The maximum number of hours that a part-time operator can work per week is often specified in the contract. A part-time operator may not receive the full benefits of a full-time operator, and may be paid at a lower wage rate.

Part-time run – see **tripper**

Passenger load is the number of passengers carried on one or more vehicles at any point on a route. Of particular interest is the maximum passenger load on a route or segment.

Passengers per minute (PPM) is the measurement of how many people accumulate every minute at all bus stops waiting for service in the direction being analyzed.

Patch is a temporary modification to a trip or series of trips on a route implemented during the sign-up period to account for a detour or to address minor running time problems.

Pattern – see **service pattern** and **schedule pattern**

Path – see **variant** and **service pattern**

Pay hours are the number of hours for which an operator is paid at his/her rate. Pay hours include work hours, make-up time, overtime premium, spread premium, and any other adjustments called for in the contract.

Pay-to-platform ratio is the ratio of pay hours to platform time. For example, if an operator receives 9:00 in pay for 8:00 of platform time, the pay-to-platform ratio is 1.125 (9:00/8:00). The pay-to-platform ratio is one of the most widely used methods of measuring runcut efficiency and is often used to measure the impacts of non-platform items (such as report allowance or relief allowances) on operator pay hours. Some systems use the inverse, the ratio of platform to pay hours.

Peak load point – see **maximum load point**

Peak periods are the hours during which ridership is highest, usually in the morning and afternoon commute times (e.g., 6 to 9 AM and 3 to 6 PM). Sometimes expressed as peak hour, the hour of highest ridership, it can also refer to the period during which the most frequent service is operated, e.g., peak 20 minutes.

Peak of the peak is the absolute busiest time interval (measured in short increments such as 15 or 30 minutes, depending on headway) during the peak period, in terms of passenger demand and service.

Peak-to-base ratio is the ratio between the number of buses or trains required to operate the schedule during the higher of the peak periods and by the number of buses in service in the "base" period between the peaks. A peak-to-base ratio of 2.0 means that twice as many buses are required to operate peak period service as midday service. The peak-to-base ratio greatly influences the runcut in terms of the number of straight and split runs that are possible. A higher ratio means more split runs.

Peak vehicles are the maximum number of vehicles required to operate the route at the required headway. Quickly calculated as round-trip cycle time divided by headway. Also referred to as "peak vehicle requirement."

Peak vehicle requirement – see **peak vehicles**

Pick – see **sign-up**

Pieces are portions of a run, especially distinct portions separated by a break.

Piece balancing is the process in which the scheduler strives to balance the number of AM and PM pieces to increase the possibility of creating split runs that are in accord with formal and informal rules and to leave a balanced number of AM and PM trippers for the extraboard to cover.

Platform time, a phrase derived from the early 20th century days when motormen and conductors operated from the "platform" of a streetcar, includes all time when the operator is operating the vehicle. Layover time and pull-in and pull-out time are part of platform time, but report allowance and clear allowance, and travel time (unless part of a pull-in or pull-out) are not. Similarly, platform miles include all miles traveled while the operator is operating the vehicle. Also known as "vehicle hours."

PM block is a block that is in service only during the PM peak period.

PM peak period is the period in the afternoon when the greatest level of service is provided, typically 3 to 6 PM.

Point check is a technique to collect information about passenger loads and schedule adherence at a single location (or point), typically a time point or a location where branches of a route diverge. Also known as "line check."

Posting is the term used for notification to operators of all work assignments that will be available for selection during the next sign-up. Runs are posted for cafeteria rostering; rosters are posted for agency-developed rostering. Runs and rosters are posted for a number of days prior to the start of actual bidding to provide time for operators to study their options prior to making their selection.

Premium pay is pay to an operator that is over and above the straight time pay rate; includes overtime premium, spread premium, shift premium, and any other operating premiums as defined by the contract.

Pull-in is the non-revenue movement of a vehicle from its last scheduled terminal or stop to the garage.

Pull-in miles are the distance the vehicle travels from the route to the garage, and are included in vehicle miles, but not in revenue miles. Collectively, pull-in miles and pull-out miles are also known as pull miles and are components of deadhead miles.

Pull-in time is the time the vehicle spends traveling from the route to the garage. Pull-in time is included in vehicle hours, but not in revenue hours. Collectively, pull-in time and pull-out time are also known as pull time and are components of deadhead time.

Pull miles – see **pull-in miles** and **pull-out miles**

Pull-off location is the place on a route where a vehicle ends revenue service.

Pull-on location is the place on a route where a vehicle begins revenue service. Also referred to as a "fit-in" point.

Pull-out is the non-revenue movement of a vehicle from the garage to its first scheduled terminal or stop.

Pull-out miles are the distance the vehicle travels from the garage to the route, and are included in vehicle miles, but not in revenue miles. Collectively, pull-in miles and pull-out miles are also known as pull miles and are components of deadhead miles.

Pull-out time is the time the vehicle spends traveling from the garage to the route. Pull-out time is included in vehicle hours, but not in revenue hours. Collectively, pull-in time and pull-out time are also known as pull time and are components of deadhead time.

Pull reliefs are reliefs made by pulling out one vehicle and pulling in another vehicle.

Pull time – see **pull-in time** and **pull-out time**

Pulse center – see **transit center**

Pulse transfer – see **timed transfer**

Recap – see **headway sheet** or **master schedule**

Recovery time – see **layover time**

Regular run – see **full-time run**

Rehooking is the process of changing how trips are linked into a block. This is done when evaluating blocks and during the runcutting process.

Relief is the replacement of one operator on a vehicle by another operator on the same vehicle. The first operator may be going on a break or may be ending his/her work day. The second operator may be starting his/her work day or coming back from a break.

Relief allowance – see **travel time**

Relief location is a designated point on a route where operators or crews may be scheduled to begin or end their run or a piece of their run. This can include the garage itself. Also known as "relief point."

Relief opportunities are times within a block when reliefs could be scheduled, typically at the end of a trip or when the vehicle passes a specified relief location.

Relief point – see **relief location**

Relief run is a run that is available as a result of other operators' day off selections. Some rosters are made up of several different relief runs.

Relief time – see **travel time**

Report – see **show-up**

Report allowance is the amount of time paid an operator from sign-in time to pull-out time. During this time, the operator may obtain instructions and supplies pertinent to his/her run, locate the assigned vehicle, and perform a pre-trip inspection.

Report time – see **sign-in time**. Sometimes used to refer to report allowance.

Revenue hours are the number of hours of service available to passengers for transport on the routes. Excludes deadhead hours, but includes layover time. Calculated for each route and for the system as a whole.

Revenue miles are the number of miles of service available to passengers for transport on the routes. Excludes deadhead miles. Calculated for each route and for the system as a whole.

Revenue service is when a vehicle is in operation along a route and is available to the public.

Ride check is a technique to collect information about boarding and alighting at every stop, in addition to passenger loads and schedule adherence at all time points. Ride checks may also include data collection on type of fare paid, stop announcements, or other information of interest to the agency. Ride checks are more labor-intensive than point checks, but provide more complete data for a given route. Also known as "on-board count" or "on-board tally."

Rostering is the process of grouping daily operator runs into packages of weekly work assignments. The finished package is known as a roster, a bid package or lines of work.

Rotating (rotary) roster is a roster where operators cycle through the weekly Lines of Work over the course of the sign-up period.

Rotation – see **headway sheet** or **master schedule**

Round-trip is a trip that travels along a route and then returns to its original starting point; a combination of two one-way trips on a route.

Round-trip cycle time – see **cycle time**

Round-trip time – see **cycle time**

Route is a defined series of stops along one or more streets between two terminal locations designated by a number and/or a name for identification internally and to the public.

Run is a work assignment for an operator. Most often, run refers to a whole day's work assignment.

Runcutting is the process of converting (or cutting) vehicle blocks into work assignments for operators. The finished product is referred to as a runcut.

Run guide is a summary of runs that describes start/finish locations, work hours, and cost element breakdowns. The Run Guide is the principal document that describes all of the runs available for bid. Also known as "Bid sheet" or "Run list."

Run list – see **run guide**

Running time is the time it takes for a vehicle to travel the length of a route or between two specific points on a route. Scheduled running time is time assigned in the schedule. Actual running time is time observed in the field. One-way running time is time in one direction along the route. Round-trip running time is time in both directions combined. Running time does not include layover time. Sometimes referred to as "travel time," although this term has an alternate meaning as defined below.

Run number is the number assigned to each work assignment on a specific day. At some systems, the run number is unique only when used in combination with a designator for the garage or the route or route group number.

Run summary is a list of runs showing start/finish times, hours worked, and paid hours. Payroll systems use the Run Summary.

Schedule is a document showing trip times at time points along a route. The schedule may also include additional information such as route descriptions, deadhead times, interline information, run numbers, and block numbers.

Schedule pattern is a summary of the schedule in terms of running times between time points and layover time at terminals. The schedule pattern can be repeated throughout the day or can change as running times and layover times change during the day.

School extras – see **school trips**

School trips or **school service** are additional scheduled trips at school bell times to accommodate the heavy loads associated with student ridership along a route. School trips are typically inserted into the schedule for no longer than necessary to address ridership demand. As with other service, these trips are scheduled to meet demand, are open to the public, and are included on public timetables. Also known as "school trippers" and "school extras."

School trippers – see **school trips**

Service area, in its broadest definition, is the area in which a transit agency provides service. This may also be defined as the area within a convenient walking distance (such as ¼ mile) of a route or a stop. For the purposes of compliance with the Americans with Disabilities Act, service area is the area within ¾ mile of a fixed route service.

Service curve is a plot of the number of buses in service by hour. See also **vehicles in operation graph**.

Service guidelines – see **service standards**

Service pattern is the unique sequence of stops associated with each type of trip on a route. If all trips operate from one end to the other on a common path the route has one service pattern. Branches, deviations or short turns introduce additional service patterns. Service patterns are a fundamental component of scheduling and provide the framework for tracking running time, generating revenue trips, and identifying deadhead movements for the route. Also referred to as "trip pattern," "variant," or "path."

Service standards are performance requirements expressed in system policies. Service standards are normally established in areas such as cost efficiency (cost per unit of service), service effectiveness (boardings per unit of service), cost effectiveness (cost and subsidy ratios), passenger loading, and schedule adherence. Many agencies also have service policies that guide the development of routes and schedules. Also known as "service guidelines."

Shake-up – see **sign-up**

Shift premium is a premium paid to operators for working during times of the day that are subject to special pay differentials, e.g., an owl (late night/early morning) run.

Short turn is a trip that terminates at an intermediate point instead of traveling the full length of the route. Short turning is frequently used to add capacity to a specific segment of the route. Also known as "turnback" or "short line."

Short line – see **short turn**

Show-up is an assignment for an extraboard operator to be at a specific location to fill in for a miss out or to do other work. A certain amount of stand-by time is paid in the event that the operator does not receive a run. Also known as "report."

Show-up time – see **sign-in time**

Sign-in time is the time an operator is assigned to report for duty at the start of each piece of a run. The operator may be required to sign in or may be acknowledged by the dispatcher as having reported. Also known as "report time," "sign-on time," or "show-up time."

Sign-on time – see **sign-in time**

Sign-up is the process in which operators select work assignments. Most agencies have three or four sign-ups each year. Sign-up is also called "bid," "line-up," "pick," "shake-up," and "mark-up."

Sign-up period is the period of time that a specific sign-up is in effect, usually three or four months.

Slipping and sliding is the process of shifting one or more trips forward or backward in time to achieve a specific purpose. Also known as "trip shifting."

Span of service is the length of time, from the beginning of the first trip to the end of the last trip, during which service operates on the street. Span of service can be expressed for a route or for the system as a whole.

Split run is a run containing two or more pieces of work separated by a break over one hour in length. Also known as a "swing run." At some systems, three-piece split runs are allowed, but one of the breaks (or "swings") is usually paid whereas in two-piece split runs the break is generally not paid. Split runs tend to be used to allow both peaks to be covered by one operator since the work day would otherwise be too long for a straight run.

Spread bonus – see **spread premium**

Spread pay – see **spread premium**

Spread penalty – see **spread premium**

Spread premium is pay at the rate equal to one-half or more of all minutes in excess of a specified maximum spread time, in addition to regular straight pay. The spread premium may be multilayered, e.g., half time up to 60 minutes over the specified maximum spread time and three-quarters or all time more than 60 minutes over the specified maximum spread time. Spread premium is separate and distinct from overtime premium. Also known as "spread penalty," "spread bonus," or "spread pay."

Spread time is the total time between the start of the first piece and the end of the last piece of a split run with two or more pieces. Also known as "outside time."

Stand-by time is the time that an operator spends at the garage at the agency's direction awaiting assignment of a run or a piece of work. Usually associated with a report by an extraboard operator, stand-by is intended to provide a pool of operators that will be available to fill runs vacated by unscheduled absences.

Storage lot is a bus storage area remote from a garage, used to minimize deadhead mileage or due to capacity constraints.

Straight run is a run in which trips are consecutive without interruption. Straight runs do not contain any breaks (except for meal breaks at some systems) for the operator. Any break in a straight run is usually less than one hour in length. A straight run with a break is referred to as a two-piece straight or multipiece straight.

Swing run – see **split run**

Swing time is the elapsed time (usually unpaid) between the pieces of a split run. Also known as "intervening time." If swing time is paid, it is sometimes called "inside time."

System bid – see **system sign-up**

System line-up – see **system sign-up**

System mark-up – see **system sign-up**

System pick – see **system sign-up**

System shake-up – see **system sign-up**

System sign-up is a scheduled sign-up during which operators may transfer from one garage to another. System sign-ups are usually held no more than once a year. At intermodal agencies, the system sign-up may allow an operator to transfer between modes as well. Also known as "system bid," "system mark-up," "system pick," "system shake-up," and "system line-up."

Terminal is one end point of a route where trips usually begin and end. Short turns and branches introduce additional terminals. Also known as "end of the line" or EOL.

Three-piece run is a run made up of three pieces of work separated by two intervals of time. Generally, one of the intervals in a three-piece run is paid time.

Through-routing is a form of interlining in which a vehicle switches from inbound service on one route to outbound service on another route while continuing in service throughout the day.

Timed transfer is a transfer made easier and more certain for passengers by the process of scheduling two or more routes to meet at a given location at a specific time. A short layover may be provided at the timed transfer point to ensure that connections can be made even if one vehicle is running slightly behind schedule. Timed transfers have become more important with the growth of hub-and-spoke network designs. Also known as a “pulse transfer.”

Time point is a designated location on a route used to control the spacing of vehicles along the route. As a rule, vehicles should not pass through a time point either before or after the specified time on the schedule. A route may contain several time points depending on its overall length. As a rule of thumb, time point spacing is usually every seven to 15 minutes along a local route, and time points are designated where possible at major intersections, major trip generators, and key destinations.

Timetable is a document containing route and time information produced for use by riders.

Traffic check is a generic term used to describe any technique to collect ridership and time-related data. Point checks and ride checks can also be referred to as traffic checks.

Traffic checkers are individuals who conduct ride checks or point checks to collect ridership and time-related data.

Train – see **block**

Train block is the series of trips operated by each train from the time it pulls out to the time it pulls in. A complete block includes a pull-out trip from the yard followed by one or (usually) more revenue trips and concluding with a pull-in trip back to the yard.

Transfer center – see **transit center**

Transfer window is the layover time scheduled at timed transfer locations to ensure that transfer connections can be made, and may also refer to the amount of time past its scheduled departure time that a vehicle can be held at a transfer location to wait for a late arriving vehicle.

Transit center is an area designed to be served by multiple routes. A transit center may be on-street or off-street, but in either case stop locations are established to facilitate passenger connections and safe vehicle movement. In radial networks, transit centers were located in downtown areas. With the emergence of hub-and-spoke networks, an agency may utilize multiple transit centers (or hubs). Also known as “transfer center,” “pulse center,” “hub,” “transit hub,” and “node.”

Transit hub – see **transit center**

Travel time is paid time allowed for an operator to travel between the garage and a relief location. If the travel is for relief purposes only and is not part of a pull-in or pull-out, then travel time is not included in platform time. Also known as “relief time,” relief allowance,” and “paid relief.”

Trip is the one-way operation of a vehicle between two points on a route. Trips are usually noted as inbound, outbound, eastbound, westbound, etc., to identify directionality. Also known as “one-way trip.”

Trip pattern – see **service pattern**

Tripper is a short piece of work whose total time is less than that specified as constituting a full-time run. A tripper is often a piece of work in the AM or PM peak period that cannot be combined with another piece of work to form a split run because of insufficient hours, excessive swing time, or excessive spread time. Trippers are often operated by extraboard or part-time operators. Also known as “part-time run.” Tripper can also refer to a vehicle that pulls out, makes no more than one round-trip, and pulls in.

Trip sheet – see **paddle** and **headway sheet**

Trip shifting – see **slipping and sliding**

Trunk is the common portion of a route with branches; more broadly, a section of a corridor served by multiple routes or trip types.

Turnback is the location where a short turn trip turns around to begin service in the opposite direction. Sometimes used to refer to the short turn trip itself.

Turn-in allowance – see **clear allowance**

Two-piece run is a run made up of two pieces of work separated by an interval of time. The pieces will usually be on different blocks and may be on different routes.

Two-piece straight – see **straight run**

Variant is a series of stops that describe a unique path. See "Service Pattern." A service pattern follows one or more variants.

Vehicle hours are total hours of travel by a vehicle, including hours in revenue service (including layover time) and deadhead travel. Also known as "bus hours" for bus. "Car hours" is the term used for rail.

Vehicle miles are total miles of travel by a vehicle, including hours in revenue service and deadhead travel.

Vehicles in operation graph is a graphical representation of the number of vehicles in operation by time of day, typically by route but also by garage or system. See also **service curve**.

Work hours are the total hours worked by an operator, not including fringe benefit hours such as sick leave, holiday, etc. Work hours include only labor hours associated with the requirements of putting the runs in service and operating the service.

Yard is the rail equivalent of "garage," the place where rail vehicles are stored and maintained.

Yard balancing is the process of ensuring that the number of train cars pulling into a specific yard at the end of the service day equals the number that pulled out at the beginning of the service day. On rail lines served by more than one yard, the same vehicles do not necessarily return to the same yard. Only the count in each yard must be the same at the end of the day as the beginning.

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Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation