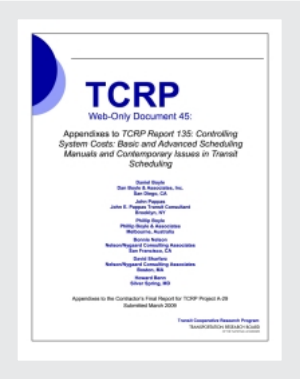
THE NATIONAL ACADEMIES PRESS

This PDF is available at http://nap.edu/22038

SHARE



Appendixes to TCRP Report 135: Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

DETAILS

0 pages | | PAPERBACK

ISBN 978-0-309-43206-1 | DOI 10.17226/22038

AUTHORS

BUY THIS BOOK

FIND RELATED TITLES

Visit the National Academies Press at NAP.edu and login or register to get:

- Access to free PDF downloads of thousands of scientific reports
- 10% off the price of print titles
- Email or social media notifications of new titles related to your interests
- Special offers and discounts

Distribution, posting, or copying of this PDF is strictly prohibited without written permission of the National Academies Press. (Request Permission) Unless otherwise indicated, all materials in this PDF are copyrighted by the National Academy of Sciences.

Copyright © National Academy of Sciences. All rights reserved.

ACKNOWLEDGMENT

This work was sponsored by the Federal Transit Administration (FTA) in cooperation with the Transit Development Corporation. It was conducted through the Transit Cooperative Research Program (TCRP), which is administered by the Transportation Research Board (TRB) of the National Academies.

COPYRIGHT PERMISSION

Authors herein are responsible for the authenticity of their materials and for obtaining written permissions from publishers or persons who own the copyright to any previously published or copyrighted material used herein.

Cooperative Research Programs (CRP) grants permission to reproduce material in this publication for classroom and not-for-profit purposes. Permission is given with the understanding that none of the material will be used to imply TRB, AASHTO, FAA, FHWA, FMCSA, FTA, TDC, or AOC endorsement of a particular product, method, or practice. It is expected that those reproducing the material in this document for educational and not-for-profit uses will give appropriate acknowledgment of the source of any reprinted or reproduced material. For other uses of the material, request permission from CRP.

DISCLAIMER

The opinions and conclusions expressed or implied in the report are those of the research agency. They are not necessarily those of the TRB, the National Research Council, the FTA, the Transit Development Corporation, or the U.S. Government.

This report has not been edited by TRB.

Copyright National Academy of Sciences. All rights reserved.

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

Copyright National Academy of Sciences. All rights reserved.

Contents

Appendix A Literature Review A-1

Appendix B Transit Agency Survey Results B-1

Appendix C Vendor Survey Results C-1

Appendix D Additional Research Needs D-1

Appendix E Case Studies E-1

Copyright National Academy of Sciences. All rights reserved.

Transit Cooperative Research Program Project A-29
Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

Appendix A
Literature Review

As part of the Transportation Cooperative Research Program's (TCRP) Project A-29, a literature review was performed on studies addressing transit scheduling conducted since the publication of the last TCRP Transit Scheduling Manual. The review focused on abstracts of major studies including TCRP Report 68 – Part Time Transit Operators: The Trend and Impacts and Report 100 – Transit Capacity & Quality of Service Manual. As specified in the project scope, the original Report 30 was reviewed. Searches were performed on the internet and more specifically on the Transportation Research Board and Transportation Research Information Services (TRIS) websites to find relevant documents and articles. All relevant materials were entered into a database and are presented.

The table on the following page summarizes the results of the literature review. The name of the report is listed first, followed by the identification number in this literature review and the page in this report on which a fuller description can be found. Each subsequent column lists specific scheduling elements. An "X" in a column indicates that the report in question includes consideration of this scheduling element.

Since this literature review focuses on research performed after the original publication of Report 30 in 1998, a bibliography at the end of the literature review lists the documents used in TCRP Report 30 and other pre-1998 materials.

Copyright National Academy of Sciences. All rights reserved.

Report	ID No.	Page	Service Standards and Policies	Blocking	Runcutting	Rostering	Service Frequency	Passenger Loads	Interlining	Running/Cycle Times	Labor Considerations	Part Time Operators	Bus Stop Analysis	Quality Considerations	Computer Applications
TCRP Report 30 Basic Scheduling Manual	1	4	X	X	X	X	X	X	X	X	X				
TCRP Report 68 Part-Time Transit Operators: The Trends and Impacts	2	6	X								X	X			
TCRP Report 100 Transit Capacity and Quality of Service Manual (2nd edition)	3	7						X					X	X	
Fixed-Route Transit Scheduling in the State of Florida: the State of the Industry	4	9		X	X	X					X				X
Case Studies in Transit Schedule Optimization	5	10		X	X	X									X
TCRP Report 95 Traveler Response to Transportation System Changes, Chapter 9: Transit Scheduling and Frequency	6	11					X							X	
TCRP Report 95 Traveler Response to Transportation System Changes, Chapter 10: Bus Routing and Coverage	7	12												X	
TCRP Synthesis 57 Computer Aided Scheduling and Dispatch in Demand Responsive Transit	8	13				X									X
TCRP Synthesis 34 Data Analysis for Bus Planning and Monitoring	9	14	X							X				X	
IDEA 12 Transit and Intermodal Scheduling Using Expert Systems	10	15	**Research in progress**												
Urban Transit Scheduling: Framework, Review, and Examples	11	16		X	X	X			X	X	X				X
A Flexible System for Scheduling Drivers	12	17													X
Transit Extraboard Management: Optimium Sizing and Strategies	13	18	**Research in progress**												
TCRP Report 30 Transit Scheduling Advanced	14	19	X	X	X	X	X	X	X	X	X				
TCRP Report 113 Using Archived AVL-APC Data to Improve Transit Performance and	15	20						X		X			X	X	X
TCRP Web Document 23 Uses of Archived AVL-APC Data to Improve Transit Performance and Management	16	22											X		X
Trapeze Case Study: Southeastern Pennsylvania Transportation Authority	17	24			X	X									X
Headway Deviation Effects on Bus Passenger Loads: Analysis of TriMet's Archived AVL-APC	18	25					X	X						X	X

Copyright National Academy of Sciences. All rights reserved.

Report	ID No.	Page	Service Standards and Policies	Blocking	Runcutting	Rostering	Service Frequency	Passenger Loads	Interlining	Running/Cycle Times	Labor Considerations	Part Time Operators	Bus Stop Analysis	Quality Considerations	Computer Applications
Automated Bus Dispatching, Operations Control, and Service Reliability: The Initial TriMet	19	26					X	X						X	X
Time-Point-Level Analysis of Transit Service Reliability and Passenger Demand	20	27								X				X	X
Service Reliability and Impacts of Computer-aided Dispatching and Automatic Vehicle	21	28								X				X	X
Evaluation of Transit Operations: Data Applications of TriMet's Automated Bus	22	29									X	X			X
Bus Transit Operations Control: Review and an Experiment Involving TriMet's Automated Bus Dispatching System	23	30													X

Copyright National Academy of Sciences. All rights reserved.

TCRP A-29 Literature Review

ID **Title**

1 TCRP Report 30 - Transit Scheduling: Basic Manual

Agency TRB

Year 1998 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics Runcutting, blocking, service policy, blocking

Service Standards & Policies - Yes
Blocking - Yes
Runcutting - Yes
Rostering - Yes
Service Frequency - Yes
Passenger Loads - Yes
Interlining - Yes

Running/Cycle Times - Yes
Labor Considerations - Yes (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - No

Purpose

Guide to aid bus schedulers in creating accurate bus schedules

Notes

The project goal is to update this manual

Summary

The report includes 5 chapters for each manual (basic and advanced). All chapters include a study objective page, quizzes, and examples.

Ch. 1: Service Policies and Schedule Development - standards and policies include route structure, service frequency, and service timing; route cycle time (roundtrip time + any layover/recovery), typical route configurations (trunk and branching, looping, short-turning), benefits of interlining (eliminate end of line loop, elimination of need for layover location, optimize cycle times, reduce transfers), types of frequencies (policy-stated that bus comes every x min, demand-freq dependent of # of passengers riding and vehicle capacity, performance-based on targeted performance standards), service timing influenced by transfer connections, trunk interlining, clock frequencies, service hierarchy.

Ch. 2: Trip Generation (process of developing the master service schedule on a route) - master schedule states times that revenue service vehicles are scheduled at specific locations, customer version is the bus timetable, considerations include: span of service, maximum load points, headways, vehicle capacity and demand (calculating load) route configuration, terminal points; cycle time-# of minutes to make a roundtrip + layover/recovery time, minimum cycle time depends on agency rules on required minimum recovery time which will directly influence number of vehicles needed in service, # of vehicles=cycle time/desired headway, excess layover/recovery time can be used to maintain consistent headway, allow route deviation, modify headways, lengthen route, facilitate interlining; intermediate time points located in between terminal locations and give more information about when buses are due at specific stops, greater than 10 minutes between stops may confuse passengers, less than 6 may lead to greater risk of bus being early, usually located at major intersections or destinations; internal time points are more detailed than public schedule and help keep route on time; controlling time points dictate arrival/departure time at a specific location that affects one or more trips along a route, relief points, timed transfer considerations,

Copyright National Academy of Sciences. All rights reserved.

developing a master schedule must take into account the format used (stops listed vertically or horizontally) and specified headway

Ch. 3: Blocking (developing vehicle assignments) - layover and recovery time and policy, blocking runs together (pull-out and pull-in time, number conventions, layover/recovery time allowance, hooking trips, calculating number of vehicles needed, costs of excessive layover/recovery time)

Ch. 4: Runcutting (process of developing driver assignments) - Straight runs (paid all the way thru), Split runs (unpaid breaks in between), runcutting must take into account platform hrs, work place rules and regulations, report and turn-in allowance, spread time (usually for split shifts - total time between the 1st report time and final turn-in time), and make-up time (payment of time not worked added to a run to bring it to the minimum daily or weekly guarantee). How to calculate # of runs needed (total platform/target platform hrs per run), chronological block listing and how to schedule split shifts. Detailed step-by-step example given.

Ch. 5: Rostering (grouping daily operator runs into weekly run packages) - typical roster mixes (weekday only, weekend plus weekday), operator developed weekly assignments (cafeteria style), agency developed weekly assignments, choose shifts generally by seniority, cost savings of each type, Operator picked - possible improved attendance, lower accidents, less complaints; Agency developed - more cost effective, can reduce overtime

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

2 TCRP Report 68 - Part Time Transit Operators: The Trends and Impacts

Agency TRB

Year 2001 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics Part Time Operators

Service Standards & Policies - Yes
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations - Yes (recovery, breaks, etc)
Part Time Operators - Yes
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - No

Purpose

Analyses the costs and benefits of using part time operators in transit operations

Notes

Summary

The report reviews advantages of PTOs such as avoiding overtime pay and making FTOs work split shifts. Net cost savings however are only 1-10% of total costs. Major factors influencing the effectiveness of PTO use are the difference in peak and base service and labor rules. PTOs typically reduce labor costs but do not necessarily improve schedule efficiency (p. 31).

Schedule efficiency increases are seen in operators who have a large peak to base ratio since more split shift opportunities are available.

Negative impacts of using PTOs include lower morale, poor labor relations due to PTO use as a bargaining chip, unattractiveness of job, and poor pay. As negatives are eliminated, more cost savings are realized. Negatives can be reduced by not requiring operators to start as PTOs and allowing PTOs to work only morning and afternoon shifts instead of requiring split shifts. By requiring PTOs to work many hours on split shifts, the attractiveness is further lowered since the operator will not be able to have a second job especially a driving job due to DOT restrictions. Training programs tailored to when PTOs can work would provide an advantage over daytime only training programs. More needs to be done to recruit and retain PTOs. Case studies include: OCTA, Denver, Portland, and more.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

3 TCRP Report 100 - Transit Capacity & Quality of Service Manual (2nd edition)

Agency TRB

Year 2002 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics Service quality, bus stop demand

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - No
Passenger Loads - Yes
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - Yes
Quality Considerations - Yes
Computer Applications - No

Purpose

Guidelines for policy makers and transit agencies providing the framework for measuring transit availability and quality of service from the passenger's standpoint.

Notes

PART 3, Ch. 4 discusses paratransit QOS

Summary

PART 3
Chapters 2 and 3 relate to bus transit and discuss quality of service (QOS) factors such as service coverage, scheduling (span and freq), capacity, information, comfort, reliability, travel time, safety/security, cost, and appearance.

Ch. 2: QOS Fundamentals
Trip decision making process - Availability (where is service located, when is it available, how do you use it, is there capacity) and Comfort and Convenience (how long is the walk, reliability, security, comfort level of travel, cost, directness, trip duration).
Service coverage must take into account walk time, bike access, ADA access, street pattern, bicycle facilities, and roadway environment
Scheduling and Capacity are key factors for transit use - if no room available, span is too short or service is too infrequent, then not a viable option.
QOS can be measured through customer satisfaction surveys and passenger environment surveys (secret shoppers)
QOS must take into account agency standards and size

Ch. 3: Fixed Route Transit Service Measures
This chapter provides level of service scales A-F for major quality measures like frequency, service span, service coverage area, etc.
Transit stops: headway frequency is major service quality measure, the more often the bus arrives, the more likely it is to attract riders; other measures are pedestrian access, bike access, ADA access, and passenger load at bus stop.
Includes detailed equations for calculating QOS

Copyright National Academy of Sciences. All rights reserved.

PART 4 (technical analysis and calculations of bus stop factors). Chapter 1 deals with bus stop loading issues and calculations. The rest of Part 4 deals with bus preferential treatment techniques and applications.
Loading capacity factors deal with how long it takes a bus to serve a stop including dwell time (how to calculate how long passengers take to board and alight) and clearance time (how to estimate time to get back into traffic). The faster a vehicle is able to serve a stop and allow for another bus to serve the stop, the higher the capacity.
Other loading area capacity factors are passenger demand (operating margin) and traffic signals.
Advantages and disadvantages of stop placement locations (near-side, far-side, mid-block) and design types (linear, saw tooth, angle, and drive through) are discussed. Person capacity of a vehicle takes into account agency policy (loading standard/limit, frequency), passenger demand (peak demand, trip length, volumes at stops), and vehicle capacity (stop capacity, vehicle capacity, etc).

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

4 Fixed Route Transit Scheduling in Florida: The State of the Industry

Agency National Center for Transit Research, University of South Florida

Year 2005 **Document Status** Final

Have a copy? Yes

Link http://www.nctr.usf.edu/abstracts/abs527-01-3.htm

Key Topics Scheduling, Software

Service Standards & Policies - No
Blocking - Yes
Runcutting - Yes
Rostering - Yes
Service Frequency - No
Passenger Loads - No
Interlining - No

Running/Cycle Times - No
Labor Considerations - Yes (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - Yes

Purpose

Examine scheduling practices at transit agencies in Florida and assess each agency's scheduling issues and potential need for technical assistance in schedule development

Notes

Summary

The document starts by reviewing the general scheduling concepts outlined in TCRP Report 30 including trip generation, blocking, runcutting, and rostering. The NCTR mailed surveys to all 25 Florida transit fixed route operators to determine scheduling practices and opinions and use of automated scheduling software. 20 of 25 responded.

Software used: Trapeze (5 agencies), 3 (GIRO Hastus), 1 (Fleetnet), 14 manual scheduling.

Operators noted that the use of software sped up scheduling, was easier to use than by hand, cut costs (less time spent on scheduling and greater scheduling efficiency led to a cut in the required # of drivers).
Use of automated scheduling software has led to greater flexibility, functionality, and control over scheduling. Also reduces mistakes, improves vehicle and operator efficiency, reduces staff time, and leads to better reporting. Small operators are interested in software but costs are too prohibitive.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

5 Case Studies in Transit Schedule Optimization

Agency GIRO (Canada)

Year 1998 **Document Status** Final

Have a copy? Yes

Link http://www.giro.ca/English/Publications/GIRO/PDF/Case%20studies

Key Topics computer scheduling

Service Standards & Policies - No
Blocking - Yes
Runcutting - Yes
Rostering - Yes
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - Yes

Purpose

Examine benefits through use of GIRO's HASTUS scheduling software

Notes

Summary

The use of HASTUS at over 175 agencies in 22 countries has resulted in cost savings and efficiency increases. HASTUS is a transit scheduling program developed by GIRO. The program allows the user to enter work rules, which greatly influence the use of labor and runcutting/blocking methods. Use of computerized programs offers fast calculation of schedules in a changing environment if immediate schedule changes due to service types or service cuts or expansions take place. Case studies were conducted in Calgary, Ottawa, Quebec, Norway, Japan, the Chunnel, and Australia.
Calgary - System offered a 3% decrease in crew costs and reduced number of school trippers needed by 3.3%
Sydney - Use of HASTUS reduced costs by 1-2%

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

6 TCRP Report 95 - Transit Scheduling and Frequency

Agency TRB

Year 2004 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics Passenger Response, Headways, Service Quality

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - Yes
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - Yes
Computer Applications - No

Purpose

Examine passenger response to frequency and scheduling changes

Notes

Summary

Scheduling and frequency modifications are among the most common service changes used to improve service effectiveness. Modifications can lead to decreased wait time for passengers, reliability, and additional convenience.

Types of changes:

Frequency changes-increasing or decreasing number of scheduled vehicle trips
Service hour changes-increasing or decreasing service hour changes
Frequency change with fare change
Combined service frequencies-increased service due to multiple routes on a street
Regularized schedules-clock face frequencies make service easy to remember and use
Reliability changes-changing scheduling to more accurately reflect actual running conditions.

Increased bus frequency led to increased usage but with varying results. No clear cut relationship is seen between increasing service frequency and patronage. Service elasticity averages 0.5 in general. The relationship is often blurred by the timing of fare increases as well as passengers shifting routes instead of modes due to frequency changes.

Effect of fare increase is greater than frequency change if service frequency is high and effect of fare increase is lower when service is infrequent. Service frequency increases will attract more transit trips, but fare revenues seldom cover the cost of increased service.

Service simplification (more direct), increased transfer coordination, and clockface/easy to use schedules also can help increase ridership.

Case studies include Boston MBTA, Santa Clarita Transit, Toronto Trolley service, and Dallas Area Rapid Transit.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

7 TCRP Report 95 - Bus Routing and Coverage

Agency TRB

Year 2004 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics Passenger Response, service changes

Service Standards & Policies - Yes	Running/Cycle Times - No
Blocking - No	Labor Considerations - No (recovery, breaks, etc)
Runcutting - No	
Rostering - No	Part Time Operators - No
Service Frequency - No	Bus Stop Analysis - No
Passenger Loads - No	Quality Considerations - Yes
Interlining - No	Computer Applications - No

Purpose

Examine passenger response to route changes and alterations including cuts and expansions

Notes

Summary

Routing and coverage changes may improve transit efficiency, effectiveness, and reach. Changes can attract choice riders and improve quality to those who are transit-dependent. Coverage and routing changes include:

New bus transit system-starting up a new system in an unserved area
Comprehensive service expansion-expanding all routes by extending service/frequency enhancements
Service changes with fare changes-alterations of service with fare changes associated
Service restructuring-reworking existing routes to improve efficiency
Changed urban coverage-providing service to unserved areas or new development or taking away service to areas
Changed suburban connections-new connections to outlying areas providing connectivity to activity centers
Circulator/Distributor routes-use of shuttles to improve connectivity in downtowns or activity centers
Feeder routes-routes serving employment centers or neighborhoods intended to bring passengers to express/line haul services
Disadvantaged neighborhoods to jobs routes-provide areas of high unemployment access to jobs not easily reached

Effect of service expansions is greater in small cities, suburbs and during off-peak times since service tends to be lower than average. Restructuring techniques that work best are emphasis on high service levels on core routes, use of consistent schedules, and more direct travel/easy transferring. Route expansions increase ridership to varying degrees depending on density. More direct routes into urban cores showed greatest gains in ridership.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

8 TCRP Synthesis 57 - Computer Aided Scheduling and Dispatch in Demand Responsive Transit Services

Agency TRB

Year 2004 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics Computer aided scheduling

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - Yes
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - Yes

Purpose

Search out useful info on computer aided scheduling and dispatching, develop best practices and current knowledge, report on problems and resolutions

Notes

Summary

This report looks at the advantages and disadvantages associated with using computer aided scheduling in demand response operations. Problems associated with the use of software focused mainly on the initial procurement and setup. Agencies in general did not have exactly what the software required. Operators were also unprepared for the amount of time it takes to set up such programs, including staff training and ensuring that the software performs the scheduling task properly and within the agency's operating limits. The use of the software has led to greater on-time rates, increase in overall service satisfaction, and a reduction in customer reported denials. The tradeoff, however, has been increased ride times for passengers.

Case studies include Charlotte Area Transit System and New Jersey Transit

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

9 TCRP Synthesis 34 - Data Analysis for Bus Planning and Monitoring

Agency TRB

Year 1999 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics Software role in data analysis

Service Standards & Policies - Yes
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - Yes
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - Yes

Purpose

Reviews the state of data analysis including ridership, running time, and schedule adherence and what computer data systems are available

Notes

Summary

Data collection is key to analyzing and reviewing routes and schedules. Common passenger count technologies include farebox counts and automatic passenger counts (APC). For vehicle location data, APCs, trip time analyzers, and automatic vehicle locators (AVL) are used. APC and time analyzers offer an advantage over AVL since they record data at events (when the doors open, for example), whereas AVL records data based on a time interval. Manual collection methods are operator trip cards, point checks, ride checks, and fare checks. In order to reduce error, constant screening of data is required. This is true for both manual methods and automatic methods.

Automated data collection is key to doing statistically valid analysis of running time and schedule adherence. Without automated techniques agencies rely on small sample sizes and anecdotal evidence to analyze routes. With automatic data, estimation is unnecessary. Most agencies do not know the statistical precision or accuracy of their estimates. Further investment and time spent procuring and using automatic data collection methods would help improve route analysis and could lead to improved service quality and scheduling.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

10 IDEA 12 - Transit and Intermodal Scheduling Using Expert Systems

Agency TRB

Year 2006 **Document Status** In Progress

Have a copy? No

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics

Service Standards & Policies	Running/Cycle Times
Blocking	Labor Considerations (recovery, breaks, etc)
Runcutting	
Rostering	Part Time Operators
Service Frequency	Bus Stop Analysis
Passenger Loads	Quality Considerations
Interlining	Computer Applications

Purpose

Notes

Abstract not included

Summary

Report is currently being researched by TRB.
Results may be beneficial to this project.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

11 Urban Transit Scheduling: Framework, Review, and Examples

Agency Journal of Urban Planning and Development

Year 2002 **Document Status** Final

Have a copy? No – Available at Journal of Urban Planning and Development V. 128, Issue 4, p. 225-244

Link

Key Topics Scheduling, Computer Programs

Service Standards & Policies - No	Running/Cycle Times - Yes
Blocking - Yes	Labor Considerations - Yes (recovery, breaks, etc)
Runcutting - Yes	
Rostering - Yes	Part Time Operators - No
Service Frequency - No	Bus Stop Analysis - No
Passenger Loads - No	Quality Considerations - No
Interlining - Yes	Computer Applications - Yes

Purpose

To construct a framework and give an overview and examples of certain practical methodologies aimed at solving the transit scheduling problems.

Notes

Author: A. Ceder
Journal of Urban Planning and Development, Vol. 128, No. 4
P. 225-244

Summary

A transit operational planning process includes 4 basic components normally performed in sequence: (1) network route design; (2) setting timetables; (3) scheduling vehicles to trips; and (4) driver assignment. This planning process is extremely cumbersome and complex and often creates confusion in its interrelationships among researchers and practitioners. The aim of this work is to construct a framework and to give an overview and examples of certain practical methodologies aimed at solving the transit scheduling problems. In the past 20 years, a considerable amount of effort has been invested in the computerization of the 4 aforementioned components. This is in order to provide more efficient, controllable, and responsive schedules. Nonetheless, despite the software used, no system is yet able to solve large scheduling problems, and manual intervention is necessary. There is a need to bridge the gap between the software system designers and the transit schedulers via the identification and organization of all the elements involved, including the current availability of data. This work emphasizes certain data needs along with examples for crystallizing and clarifying the transit scheduling undertaking. It is suggested that most of the scheduling tasks be performed automatically, but it is preferable to undertake some of them through a conversational man-computer mode.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

12 A Flexible System for Scheduling Drivers

Agency Journal of Scheduling

Year 2003 **Document Status** Final

Have a copy? No – Available at Journal of Scheduling, v. 6, Issue 5, p. 437-455

Link
http://portal.acm.org/citation.cfm?id=1008545&dl=acm&coll=&CFID=15151515&CFTOKEN=6184618

Key Topics Using computer programming

Service Standards & Policies - No	Running/Cycle Times - No
Blocking - No	Labor Considerations - No (recovery, breaks, etc)
Runcutting - No	
Rostering - No	Part Time Operators - No
Service Frequency - No	Bus Stop Analysis - No
Passenger Loads - No	Quality Considerations - No
Interlining - No	Computer Applications - Yes

Purpose

Using TRACS II to provide maximum efficiency and flexible operators schedules in transit scheduling

Notes

Summary

Algorithmic advances and enhanced computing power have led to progress in achieving better schedules. Differences in labor rules make general software difficult. TRACS II has overcome difficulties and has been successfully implemented at a number of bus and train operations.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

13 Transit Extraboard Management: Optimum Sizing and Strategies

Agency National Center for Transit Research, University of South Florida

Year 2006 **Document Status** In Progress

Have a copy? No

Link http://www.nctr.usf.edu/publications.htm

Key Topics Extraboard Drivers, Scheduling

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations (recovery, breaks, etc)
Part Time Operators - Yes
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - No

Purpose

Using extraboard driver resources most efficiently

Notes

Summary

Study is in progress at the NCTR in Florida. Results may be beneficial to this project. This study intends to seek ways of best using driver resources and extraboard drivers to schedule shifts most efficiently.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

14 TCRP Report 30 - Transit Scheduling: Advanced Manual

Agency TRB

Year 1998 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics Service standards and policies, blocking, runcutting, rostering

Service Standards & Policies - Yes	Running/Cycle Times - Yes
Blocking - Yes	Labor Considerations - Yes (recovery, breaks, etc)
Runcutting - Yes	
Rostering - Yes	Part Time Operators - No
Service Frequency - Yes	Bus Stop Analysis - No
Passenger Loads - Yes	Quality Considerations - No
Interlining - Yes	Computer Applications - No

Purpose

Like the Basic Manual, the Advanced Manual is intended for use by transit operators in schedule making and shift assignment

Notes

Summary

The Advanced Manual takes an in-depth look at topics mentioned in the Basic Manual and includes detailed examples and problems.

Ch. 1: Service Policy and Schedule Development - ride checks to determine maximum load points and stop level activity; need to examine calculated running times, schedule adherence data, AVL data, stop inventory, and dwell time requirements to determine running times; time/loading data collection using AVL/APC, point checks, ride checks, NTD checks, trail checks, farebox and operator counts, operator interviews; based on Information, service level can be changed as well as running time adjustments.

Ch. 2: Trip Generation - scheduling complex routes with different branches, route design (should serve major destinations, determine route pattern, optimize cycle time by hooking trips (short and long trips), branch interlining can lead to balanced run times, increased circulation by not using one way loops, more efficient spacing of vehicles; controlling time points are used at major trip generation points, pull-on and pull-off locations, transitioning from peak to base, adding school trips into schedule; includes rail discussion including single track and multi track operations.

Ch. 3: Blocking - blocking uses same idea in complex operating environment as simple environment by hooking trips; this chapter reviews complex example, notes that certain blocks are peak only/school only, make block graphs in order to combine blocks together or rearrange.

Ch. 4: Runcutting - before runcutting, review work rules and estimate # of runs; blocking is often reevaluated during runcutting to maximize efficiency, in order to runcut (1 method), split full day blocks (straight runs) into two runs, combine peak services into split runs, make chronological block listing, combining split runs (can be tricky - all labor rules must be considered), find runcut efficiency by computing ratio of pay hours to platform hours, relief location notation.

Ch. 5: Rostering - how to calculate # of operators (# of runs/work days in a week), calculating days off per day type(# of operators - daily runs), examples included: analyzing efficiency, combining 4 and 5 day schedules.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

15 TCRP Report 113 – Using Archived AVL-APC Data to Improve Transit Performance and Management

Agency TRB

Year 2006 **Document Status** Final

Have a copy? Yes

Link http://www.tcrponline.org/bin/publications.pl?category=2

Key Topics

Service Standards & Policies - No	Running/Cycle Times - Yes
Blocking - No	Labor Considerations - No (recovery, breaks, etc)
Runcutting - No	
Rostering - No	Part Time Operators - No
Service Frequency - No	Bus Stop Analysis - Yes
Passenger Loads - Yes	Quality Considerations - Yes
Interlining - No	Computer Applications - Yes

Purpose

Provide direction and insight on the use of AVL-APC and other add ones in analyzing bus operations including run times, schedule adherence, service quality, and load factors

Notes

Summary

Current AVL and APC systems gather an enormous amount of data that can help transit planning. The data is often underutilized due to a focus on real time data (system is unable to capture data for offline use) or data analysis tools are not available.

This report offers guidance in 5 areas

1. Analyses that can use AVL-APC data to improve management and performance
2. AVL-APC system design that facilitates the capture of data with the accuracy and detail needed for off-line data analysis
3. Data structures and analysis software for facilitating analysis of AVL-APC data
4. Screening, parsing, and balancing automatic passenger counts
5. Use of APC systems for estimating passenger-miles for NTD reporting

AVL systems gather 3 types of records: polling records, stop records, and time-point records. Polling records indicate vehicle location at a specific moment in real-time. Stop and time-point records record data about when buses depart and/or arrive at specified points. Data can be recorded by the door open point or when the vehicle arrives at a certain proximity to a stop. Stop records offer greater geographic data since data is recorded by stop instead of time-point. This includes hold times and records when the bus doesn't stop. Stop level data can aid in planning published schedules, computer trip planning, and next bus arrival predictions. AVL and APC data also can be configured to record events such as engine on/off, radio use, lift activation, etc. This data can be useful to record or analyze pass-ups and various delays. AVL systems can store data on board or send via radio transmission. Radio transmission provides less data since the recording frequency is less often than on board storage. When used together AVL, APC, radio control head, odometer, gyroscope, door sensors, wheelchair lift sensors, farebox data, and stop enunciators can provide a huge benefit to passengers, drivers, and a wealth of information.

Copyright National Academy of Sciences. All rights reserved.

The uses for the data received are far reaching. Data can be used on targeted investigations such as passenger complaints, legal claims, and payroll disputes. The ability to "playback" exactly where was at a specific time, enables easier investigation. One of the best uses of the data is for **run-time analysis**. This data can track schedule adherence in relation to the schedule and provide a huge sampling size as high as 85-95% of all runs instead of small samples used for manual analysis. The data can analyze the extreme values of being early or late and hence service quality by analyzing bus stop wait times for passengers. APC data can analyze passenger load factors at stops along the route allowing agencies to see where/if more or less service is needed. Also routes can become more efficient. By knowing exactly where passengers board and alight, planners can add or remove stops from routes. The data can also be used to track driver performance by analyzing if drivers are leaving on-time or departing early. Very frequent observations or accelerometers can even go as far as calculating how smooth the ride is for passengers.

The recorded data is accurate enough to be used for NTD required ridechecks even if only a small sample of the fleet is equipped with APCs.

Advanced/customized programming can be very helpful but the level of database expertise is often to available at transit agencies. Ideally, externally supplied software should be made modular to allow customization of data queries and report formatting allowing the agency to choose what they want/need to analyze. The software should provide the user however to manipulate and analyze the data any way they please however and give them the ability to access all the raw data.

Tools developed for analyzing APC and AVL data are available on the TRB website including passenger wait time and passenger crowding analysis spreadsheets in TCRP Project H-28. Tools for analyzing running times, designing scheduled running times, and analyzing advanced data structures like multiple routes serving the same streets/stops were created as an extension of the existing software TriTAPT (Trip Time Analysis in Public Transport).

Case studies include Seattle, Portland, Chicago, New Jersey, Minneapolis, Ottawa, Montreal, and The Hague and Eindhoven in the Netherlands.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

16 TCRP Web Document 23 - Uses of Archived AVL-APC Data to Improve Transit Performance and Management

Agency TRB

Year 2003 **Document Status** Final

Have a copy? Yes

Link http://trb.org/news/blurb_detail.asp?id=1699

Key Topics Public transportation administration and management, data and information technology, and planning

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - Yes
Quality Considerations - No
Computer Applications - Yes

Purpose

To provide a coherent framework to coordinate operations, planning, and scheduling functions in the collection and use of AVL-APC data. The purpose is also to provide potential applications of the data for analyzing fixed route services.

Notes

Summary

This is a companion report to TCRP Report 113, available only on the web. In order to review AVL-APC practices and uses in the industry, a literature review was performed on ITS, a mail survey was distributed to US transit agencies, a telephone survey and case studies were performed of US, Canadian, and European agencies, and a workshop was held for AVL-APC vendors.

Findings and Guidance:
Stop level data is generally more desirable than timepoint level data. Stop level data provides more detailed accuracy of bus location and holding and running times. Stop level data also lends itself to more accurate scheduling, can support signal priority, and can be more easily integrated with APC equipment.

Location at time data is preferred to time at location data since almost all time-oriented applications are based upon arrival and departure times from locations of interest (timepoints).

Summary level detail between stops is sufficient for most planning purposes. Detailed data can be stored and used for research or investigations if needed.

Radio to central computer transmission allows for immediate analysis and real time tracking. It also allows for storage at a central location without having to download the data from each bus.

Limitations on bandwidth, etc. can prevent radio to central computer transmission. In order to get a comprehensive review of an entire system, however, onboard data storage has the fewest limitations.

Copyright National Academy of Sciences. All rights reserved.

Full coverage of the fleet is recommended for time-location data and 10%-100% coverage for passenger counters.

Better analysis tools are needed to better utilize archived data from ITS.

Managing AVL-APC data is time consuming and takes some level of expertise. Data needs to be checked for quality control. More standard analysis tools are necessary. As the technology becomes more available and easier to use, less staff time should be necessary.

APC-AVL data can create planning and scheduling opportunities not seen in the past. More data management tools are necessary however in order to unlock the potential of the data.

Opportunities: Speed profiles, simulations, updating base maps, more accurate schedules, fare collection, NTD reporting

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

17 Trapeze Case Study: Southeastern Pennsylvania Transportation Authority

Agency Trapeze

Year 2003 **Document Status** Final

Have a copy? No

Link http://www.trapezegroup.co.uk/newsevents/cs_050216.php

Key Topics Using Trapeze in scheduling to improve efficiency

Service Standards & Policies - No
Blocking - No
Runcutting - Yes
Rostering - Yes
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - Yes

Purpose

Analyzing the effects of switching from manual scheduling to Trapeze for fixed route services at SEPTA

Notes

Summary

In order to improve efficiency and modernize scheduling, SEPTA contracted with Trapeze to use their software to schedule drivers and perform runcutting.

Since the Trapeze system went live, it has delivered substantial savings in vehicle and operator costs. In some divisions, the number of runs has been reduced by as much as 3.4%, and driver pay hours are down by 1.5%. This amounts to savings of more than $900,000 per year. Service levels have not been reduced in this period.

In addition to shrinking operating costs, SEPTA has also moved toward a more integrated IT environment. Web and IVR customer information and other enterprise applications, such as payroll, are fed with data from the scheduling system. It is easier to ensure that consistent data is being communicated, and easier to maintain and update the data.

SEPTA partly attributes the success of the fixed route scheduling project to the strength of the training and the expertise and attentiveness of the Trapeze team.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

18 Headway Deviation Effects on Bus Passenger Loads: Analysis of TriMet's Archived AVL-APC Data

Agency Center for Urban Studies
College of Urban and Public Affairs
Portland State University

Year 2003 **Document Status** Final

Have a copy? Yes

Link http://www.upa.pdx.edu/CUS/publications/docs/PR126.pdf

Key Topics AVL-APC data, computer applications,

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - Yes
Passenger Loads - Yes
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - Yes
Computer Applications - Yes

Purpose

Analyze the effect of headway deviation (late buses) on passenger loads and capacity using AVL-APC data

Notes

Summary

Bus bunching results in frequent passenger overloads on routes. Bus bunching occurs when buses run outside of their normal headway. Due to the use of AVL-APC collectors on TriMet vehicles, TriMet was selected as the case study.

Estimation results indicate that headway delays are a primary cause of passenger overloads and a modest reduction in headway delay would lead to a substantial reduction in overloads. Service regularity improvements can be more accessible using AVL-APC data and can lead to reduced waiting time and uncertainty for passengers and lower operating and capital costs for transit providers.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

19 Automated Bus Dispatching, Operations Control, and Service Reliability: The Initial TriMet Experience

Agency Center for Urban Studies
College of Urban and Public Affairs
Portland State University

Year 1999 **Document Status** Final

Have a copy? Yes

Link http://www.upa.pdx.edu/CUS/publications/docs/PR110.pdf

Key Topics AVL-APC data analysis

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - Yes
Passenger Loads - Yes
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - Yes
Computer Applications - Yes

Purpose

Present findings on initial changes in service reliability following TriMet's deployment of new bus dispatching systems using AVL-APC technology

Notes

Summary

Data was analyzed to determine bus reliability improvements before AVL-APC data was implemented and after it was implemented.

On-time performance increased 9.4% to 67.2%. The improvement in on-time performance was largely attributable to a substantial decline in early arrivals. Overall late arrivals actually increased 14%. The use of AVL data also led to a 15% decline in bus bunching. Improvements due to the new technology have lead to reductions in passenger wait times and in-vehicle travel times and operator running time improvements.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

20 Time Point-Level Analysis of Transit Service Reliability and Passenger Demand

Agency Center for Urban Studies
College of Urban and Public Affairs
Portland State University

Year 2001 **Document Status** Final

Have a copy? Yes

Link
http://www.upa.pdx.edu/CUS/publications/docs/SR036.pdf?bcsi_scan_EAC41357C45D053C=0&bcsi_scan_filename=SR036.pdf

Key Topics AVL-APC data

Service Standards & Policies - No	Running/Cycle Times - Yes
Blocking - No	Labor Considerations - No (recovery, breaks, etc)
Runcutting - No	
Rostering - No	Part Time Operators - No
Service Frequency - No	Bus Stop Analysis - No
Passenger Loads - No	Quality Considerations - Yes
Interlining - No	Computer Applications - Yes

Purpose

Provide a framework for analyzing transit service reliability and estimating passenger demand at time point level of analysis

Notes

Summary

Using modeling, results suggest that reducing delay variation at time points by using control actions such as vehicle holding will produce benefits to passengers in the form of more predictable service. Building enough running time into schedules will allow operators to adjust vehicle speeds and stopping activity to better maintain reliability.

Delays increase as scheduled service increases. Results showed that alighting activity had a more profound impact on reliability than boarding activity.

Bus stop consolidation may be a realistic option for streamlining service and preventing delays.

Demographic factors like high population and employment densities and the number of zero vehicle households result in sizeable increases in ridership.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

21 Service Reliability and Impacts of Computer-Aided Dispatching and Automatic Vehicle Location Systems

Agency Center for Urban Studies
College of Urban and Public Affairs
Portland State University

Year 1999 **Document Status** Final

Have a copy? Yes

Link http://www.upa.pdx.edu/CUS/publications/docs/PR125.pdf

Key Topics AVL-APC data analysis

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - Yes
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - Yes
Computer Applications - Yes

Purpose

Present findings on initial changes in service reliability following TriMet's deployment of AVL-APC technology including changes in on-time performance, headway variation, and run time variation in comparison with pre-deployment levels

Notes

Summarized in TCRP Web Document 23

Summary

After implementation of AVL-APC technologies, on-time performance increased over 9% to 67%. Most of the improvements are seen in the decline in early arrivals and late arrivals actually increased by more than 14%. Service regularity improved with a 5% reduction in headway variation and bus bunching declined by 15%. Overall benefits of using the new technology are reduced passenger waiting times, reduced passenger in-vehicle travel times and operator running time improvements.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

22 Evaluation of Transit Operations: Data Applications of TriMet's Automated Bus Dispatching System

Agency Center for Urban Studies
College of Urban and Public Affairs
Portland State University

Year 2001 **Document Status** Final

Have a copy? Yes

Link http://www.upa.pdx.edu/CUS/publications/docs/PR120.pdf

Key Topics Use of AVL-APC data in service analysis

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations - Yes (recovery, breaks, etc)
Part Time Operators - Yes
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - Yes

Purpose

Employ archived trip level running time data to assess schedule efficiency and use archived data to estimate a fixed effects model addressing operator-related variations in running time

Notes

Summarized in TCRP 113

Summary

Scheduled recovery times typically exceed the amount that operating experience indicates would be sufficient. A substantial amount of variation in running times can be linked to variations in operator behavior.

Options available to reduce operator variation include reducing reliance on part time operators who tend to contribute to greater running time variability. Also grouping together operators with similar experience improves service regularity. Additional field supervision would also contribute to improving performance.

Copyright National Academy of Sciences. All rights reserved.

ID **Title**

23 Bus Transit Operations Control: Review and an Experiment Involving TriMet's Automated Bus Dispatching System

Agency Center for Urban Studies
College of Urban and Public Affairs
Portland State University

Year **Document Status** Final

Have a copy? Yes

Link http://www.upa.pdx.edu/CUS/publications/docs/PR117.pdf

Key Topics Use of AVL-APC data, operations control

Service Standards & Policies - No
Blocking - No
Runcutting - No
Rostering - No
Service Frequency - No
Passenger Loads - No
Interlining - No
Running/Cycle Times - No
Labor Considerations - No (recovery, breaks, etc)
Part Time Operators - No
Bus Stop Analysis - No
Quality Considerations - No
Computer Applications - Yes

Purpose

The purpose of this paper is to review operations control principles and practices reported in literature and report the results of an operations control experiment whose objective was to maintain headways on TriMet bus routes

Notes

Summarized in TRCP 113

Summary

First generation operations research on headway adherence concluded that holding imposes costs on passengers already on board vehicles in the form of increased travel time, imposes costs on transit providers in the form of increased running times, control points work best when the control point has light boarding activity and demand is heavy immediately after the point, headway variability increases after the control point and may prove to be detrimental in some situations.

Second generation operations control research concluded that holding is more effective at earlier points along a route, human factors play an important role on control practices, short turning, stop-skipping, and deadheading are the second best solution to improve headway adherence.

Based on the TriMet experiment using real-time AVL-APC data, headway regularity was substantially greater at the location of the control action and headway regularity generally tended to be better in the initial stages of the trip.

Dispatchers involved in the experiment noted that there is a need and opportunity for automating real time operation control actions since dispatchers cannot always respond immediately.

Copyright National Academy of Sciences. All rights reserved.

Bibliography

Advances in Bus Planning Practices. Transportation Research Board, NRC, Washington D.C., 1985.

Algorithms for Routing and Scheduling in Demand Responsive Transportation Systems. Research Publication GMR-944. GMC Research Labs, Warren, MI, 1970.

Altoji, Joseph. Labor Supply Preferences, Hours, Constraints, and Hour Wage Trade-Offs. Nation Bureau of Economic Research, NBER Working Paper #2121, Cambridge, MA, 1987.

An Optimization Model for Determining Headways for Transit Routes. Marquette University, Milwaukee, WI, August 1974.

Barnett, Jonathan. Development of Analytical Techniques for Risk Management Training. FTA Office of Technical Assistance & Safety, Washington D.C., 1992.

Basics of Route and Service Design. BC Transit Service Planning, May 1990.

Bassily, Fady F. Development of Track Maintenance Training and Maintenance Management Information System Programs. FTA Office of Technical Assistance & Safety, Washington D.C., 1992.

Beseltine, F.M. et all. Working Practice in the Bus Industry: Recent Changes in Planning and Transportation Research and Computation. Vol. P319, 1989.

Blau, Margaret E. A Personnel Scheduling Management System for the Washington State Department of Transportation Field Offices: An Investigation of Current Practices, Needs and Design Specifications. Washington DOT, Olympia, WA, 1988.

Bodin, L. The State of the Art in the Routing and Scheduling of Vehicles and Crews. University of Maryland, College Park, MD, September 1981.

Bus Route Costing Procedures: A Review. Report No. UMTA-IT-09-9014-81-1, US DOT, May 1981.

Bus Transit Monitoring Manual (2 Volumes). Report No. UMTA-IT-09-9008-81-1, US DOT, August 1981.

Cedar, A. and Stern, H. Graphical Person-Machine Interactive Approach for Bus Scheduling. Transportation Research Record 857, Transportation Research Board, 1982.

Cedar, Avishai. Optimal Design of Transit Short-turn Trips. Transportation Research Board Annual Meeting, 1989.

Cherwony, Walter & Polin, Lewis. Improving Transit Utilization through Pulse-Scheduling. Transit Journal (vol. 3#2), APTA, 1977.

Christiansen, Kathleen. Flexible Staffing and Scheduling in U.S. Corporations. New York, 1989.

Copyright National Academy of Sciences. All rights reserved.

Coffel, Bill. TRI-MET Scheduling Practices. Tri-County Metropolitan Transit District, Portland, OR, January 1993.

Drake, Richard, Douglas W. Carthy. Public Transit Bus Maintenance Manpower Planning. TRB/NRC, Washington D.C., 1984.

Elias, Samy E. G. A Mathematical Model for Optimizing the Assignment of Man and Machine in Public Transit "Run-Cutting". West Virginia University, Morgantown, WV, 1966.

Elias, Samy E. G. The Use of Digital Computers in the Economic Scheduling of Both man and Machine in Public Transportation. Special Report No. 49, Kansas City University, Manhattan, KN, 1966.

Ellis, Ralph D. Developing Night Operations in Florida. Department of Civil Engineering, University of Florida Gainesville, 1992.

Estimation of Operating and Maintenance Costs for Transit Systems: A Final Report. KPMG Peat Marwick Main, Washington D.C.: US DOT, FTA, 1993.

Feasibility of a Complimentary Solution to the Bus Operator Scheduling Problem. West Virginia University, Morgantown, WV, December 1979.

Furth, P. and Wilson, N. Setting Frequencies on Bus Routes: Theory and Practice. Transportation Research Record 818, pp. 1-7, 1981.

Glossary of Transit Terminology. American Public Transit Association, Washington D.C.

Grant, David. Days Off Calculator Version 2.0 User's Guide. New Orleans, 1994.

Hufstedler, Gary. Incremental Runcutting. Presented at the Operations Planning Workshop, Federal Transit Administration, Washington D.C., 1993.

Kuznyak, Richard et all. A Review of State-of-the-Practice of Matching Operators and Buses. Urban Mass Transportation Administration, Washington D.C., 1985.

Levinson, Herbert. Supervision Strategies for Improved Reliability of Bus Routes. UMTA, Washington D.C., 1991.

MacDorman, Littleton C. & Dianne S. Schwager. Transit Employee Attendance Management. UMTA, Washington D.C., 1988.

Maze, T.H., Kathleen Wagner. Manual for Contracting for Vehicle Maintenance Services. FTA Office of Technical Assistance & Safety, Washington D.C., 1992.

Niemeyer, James M. Introduction to Fixed Route Transit Scheduling & Time Management. Blocks & Runs, Plano, TX, May 1994.

Niemeyer, James M. Local Service Vehicle & Driver Scheduling: Operations Guide. Saudi Public Transport Company, Riyadh, Saudi Arabia, April 1984.

Copyright National Academy of Sciences. All rights reserved.

Operating Schedules: Training Material. Public Service Coordinated Transport, Maplewood, NJ, 1969 (Reprinted in November 1979).

Parry, S. Clock Face Headways. Presented at the Operations Planning Workshop, Federal Transit Administration, Washington D.C., 1993.

Perry, James L. Extraboard Scheduling, Worker's Compensation and Operator Stress in Public Transit: Research Results and Managerial Impact. Institute for Transportation Studies, Irvine, CA, 1984.

Pierce, Jon L. et al. Alternative Work Schedules. Allyn/Bacon, Boston, MA, 1989.

Qiu, Jun. Bus Stop Based Schedule Database for the Transit Time Internet Access System. The Center for Urban Studies, Portland State University, Portland, OR, September 1996.

Rainville, Walter S. Traffic Checking and Schedule Preparation: Part II – A Survey of Current Industry Practices, Second Report – Passenger Load Data. American Transit Association, New York, April 1949.

Rainville, Walter S. Traffic Checking and Schedule Preparation: Part III – An Industry symposium, Second Report – An Industry Symposium on Passenger Load Data. American Transit Association, New York, September 1949.

Rainville, Walter S. Traffic Checking and Schedule Preparation: Part III – An Industry symposium, Third Report – An Industry Symposium on Running Time Data. American Transit Association, New York, January 1950.

Rainville, Walter S. Bus Scheduling Manual: Traffic Checking and Schedule Preparation. American Transit Association, New York, 1947 (Reprinted July 1982).

Roberts, Kenneth R. Vehicle Scheduling and Driver Run-Cutting - RUCUS Package Overview. The Mitre Corp., Washington D.C., September 1971.

Scheduling Manual. Calgary Transit Schedules Unit, 1983.

Smerk, George. Human Resources in Transit Conference: A Summary of Proceedings. US DOT & FTA, Washington D.C., 1992.

Summary of an Automated Scheduling System for Demand Responsive Public Transportation. The Mitre Corp., March 1974.

Transit Management Programs: Course Syllabus. University of Southern California, The Institute of Safety and Systems Management, Newport Beach, CA, 1988.

Transit Route and Schedule Information Methods. University of Texas at Arlington, August 1976.

University of Wisconsin-Milwaukee. Fixed Routes Scheduling/Run-Cutting Workshop. Presentation, 1993.

Copyright National Academy of Sciences. All rights reserved.

United States Department of Transportation. Software and Source Book. Microcomputers in Transportation, Urban Mass Transportation Administration, 1986.

Urban Public Transportation Glossary. Transportation Research Board, NRC, Washington, D.C., 1989.

Wiggins, Martin. Traffic Checking Manual. Dallas, TX, 1987.

Copyright National Academy of Sciences. All rights reserved.

Transit Cooperative Research Program Project A-29
Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

Appendix B
Transit Agency Survey Results

B.1 Introduction and Methodology

The Transit Agency Survey, undertaken as a Phase I task of TCRP Project A-29, was developed as a tool for understanding the state of the practice in scheduling at transit properties of different sizes, for identifying the challenges facing transit operators as they schedule their system, and to assist in identifying agencies for detailed case study analysis in Phase II of the project.

The survey, provided in the final section, included nearly 200 questions organized in topic groups, including general scheduling issues, organization, schedule writing, running time and layover, blocking, runcutting, rostering, and computerized scheduling. Survey results will guide the team as it designs a scheduling manual to address basic and advanced scheduling techniques and to shed light on contemporary scheduling issues.

A total of 60 agencies were included in the survey sample, including:

- 15 small agencies with fewer than 100 peak vehicles in service;
- 19 medium agencies with 100 to 500 peak vehicles in service;
- 21 large agencies with over 500 peak vehicles in service

TCRP panel members reviewed preliminary lists of agencies and recommended additions to ensure a representative sample across several key criteria including agency size, operational complexity, computerized/manual methods, and a range of scheduling approaches & issues. Team members sent emails to each agency in the sample describing the project, soliciting participation, and asking for the most appropriate contact at each agency. The team also prepared a brief article for *Passenger Transport* encouraging participation by agencies not included in the sample, but due to space considerations, the article never appeared.

The majority of respondents elected to complete the survey on-line using the webpage established on the “Survey Monkey” website for this purpose. Alternate formats (electronic or hard copy) were available upon request.

Daily tallies of completions were compiled, and agencies that had not yet completed the survey received at least two personal phone calls and/or e-mails requesting that they complete the survey. Where necessary, substitutions were made to ensure that a well-balanced response could be maintained. The survey period began on Monday, February 5, 2007 and was officially closed on Friday, March 30, 2007.

Of the 60 agencies that were contacted about the survey, 51 fully completed the survey (85 percent). Another four agencies partially completed the survey, and the remaining five did not respond to the survey. Three of the five non-responding agencies were in the midst of organizational changes. Overall, 55 of the 60 agencies in the sample (92 percent) provided at least a partial response, reflecting a very high level of interest in this topic.

Copyright National Academy of Sciences. All rights reserved.

Each section of this report presents survey results related to a specific topic area. Results are generally summarized by agency size. Topic areas include:

- General scheduling practices
- Schedule writing
- Running time and layover/recovery time
- Blocking
- Run cutting
- Rostering
- Computerized scheduling
- Organization and training
- Other issues

Among all the information provided by transit agencies in this survey, responses regarding constraints that limit a scheduler's ability to produce efficient schedules are essential in deepening our understanding of how scheduling functions in the real world and enabling us to provide useful guidance in the new manual. Constraints take the form of contract rules, past practices, insufficient training or resources, and reluctance to explore new techniques. Constraints and factors affecting each element of scheduling are included in the following sections.

The final section of this report (*"Toward the Manual"*) presents agency issues and needs as reported on the survey and also summarizes all survey results in terms of aspects of scheduling that will require particular attention in the manual.

Copyright National Academy of Sciences. All rights reserved.

B.2 General Scheduling Practices

Participating transit agencies were asked to rank the primary reasons that they revise their schedules. Service changes are the primary reason for revising schedules. The second most common motivation for updating schedules was ridership growth for both large and small operators, and bid requirements for the medium sized agencies. Labor agreement changes were among the least common reasons for updating schedules

Q11. Please rank from 1 (most important) to 6 (least important) the following as driving forces causing the need to update schedules blocks and runs

Small Agencies		
Service changes	1.43	Most Important
Labor agreement changes	4.71	6th
Regular bid requirements	3.62	5th
Budget issues	3.29	3rd
Ridership growth	2.79	2nd
Other	3.40	4th

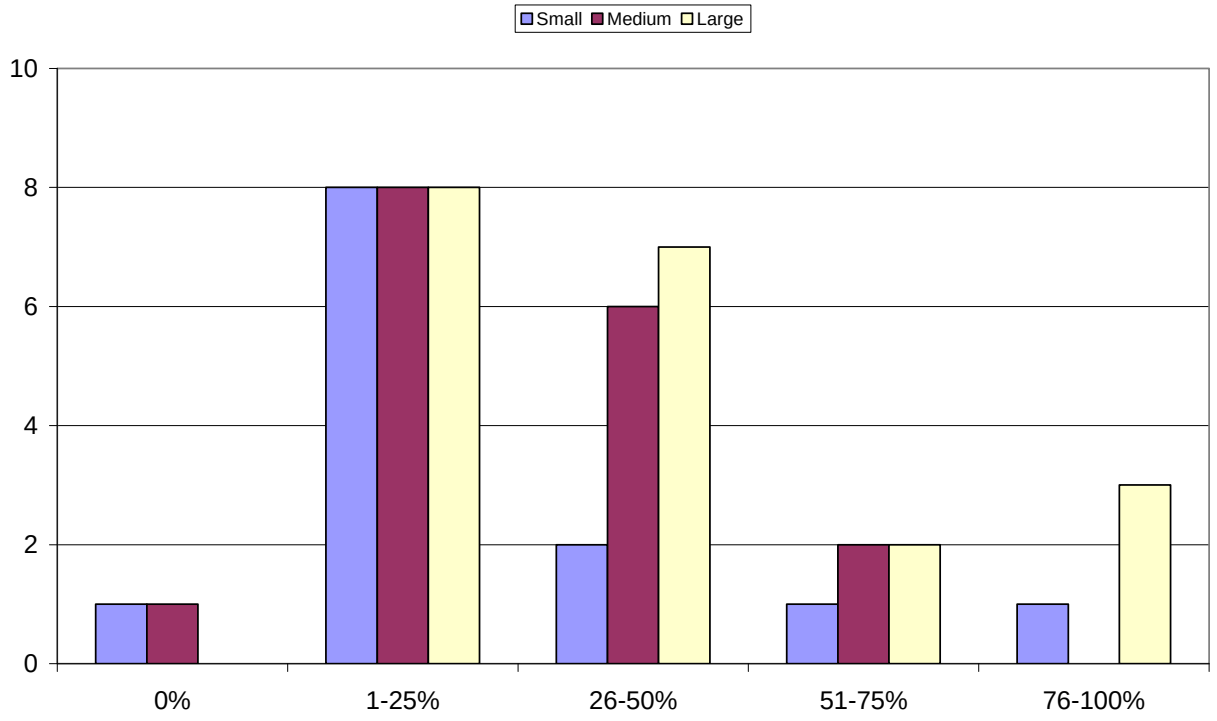
Medium Sized Agencies		
Service changes	1.39	Most Important
Labor agreement changes	4.53	5th
Regular bid requirements	2.88	2nd
Budget issues	3.28	4th
Ridership growth	3.22	3rd
Other	5.00	6th

Large Agencies		
Service changes	1.62	Most Important
Labor agreement changes	4.90	6th
Regular bid requirements	3.15	3rd
Budget issues	3.33	4th
Ridership growth	2.62	2nd
Other	3.90	5th

Copyright National Academy of Sciences. All rights reserved.

With service changes being a primary reason for updating schedules, agencies were asked how much of their service changes in any given year. Almost half the agencies surveyed indicated that no more than one-quarter of their routes undergo service changes in any given year. This implies that on average routes are being addressed every four years. Small agencies reported fewer service changes.

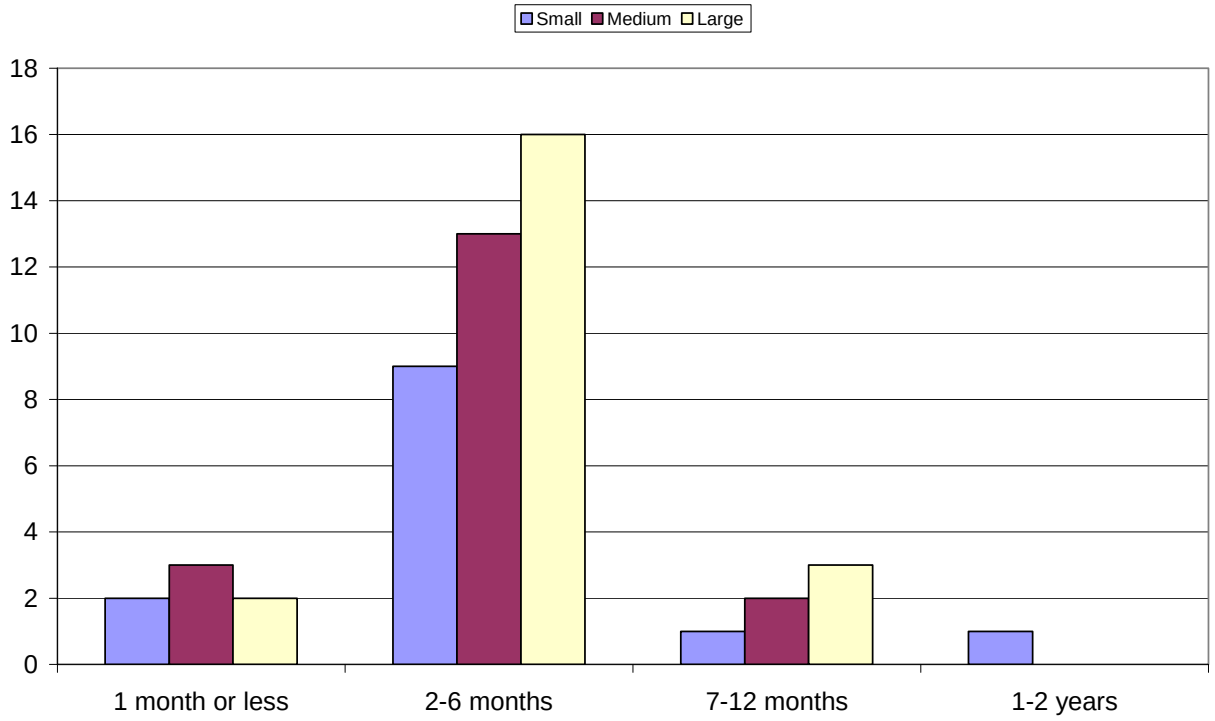
Q14. Typically, what percentage of your agency's routes have service changes in any given year?



Copyright National Academy of Sciences. All rights reserved.

Most agencies indicated that the schedule creation process takes six months or less from concept to implementation. Agencies that reported a longer time frame were most often large agencies with either more complex schedules or procedures that lengthened the bid process. A cross-tabulation of length of the schedule creation process versus computerized/non-computerized scheduling was unrevealing, in part because almost all medium and large agencies in the sample use a computerized package.

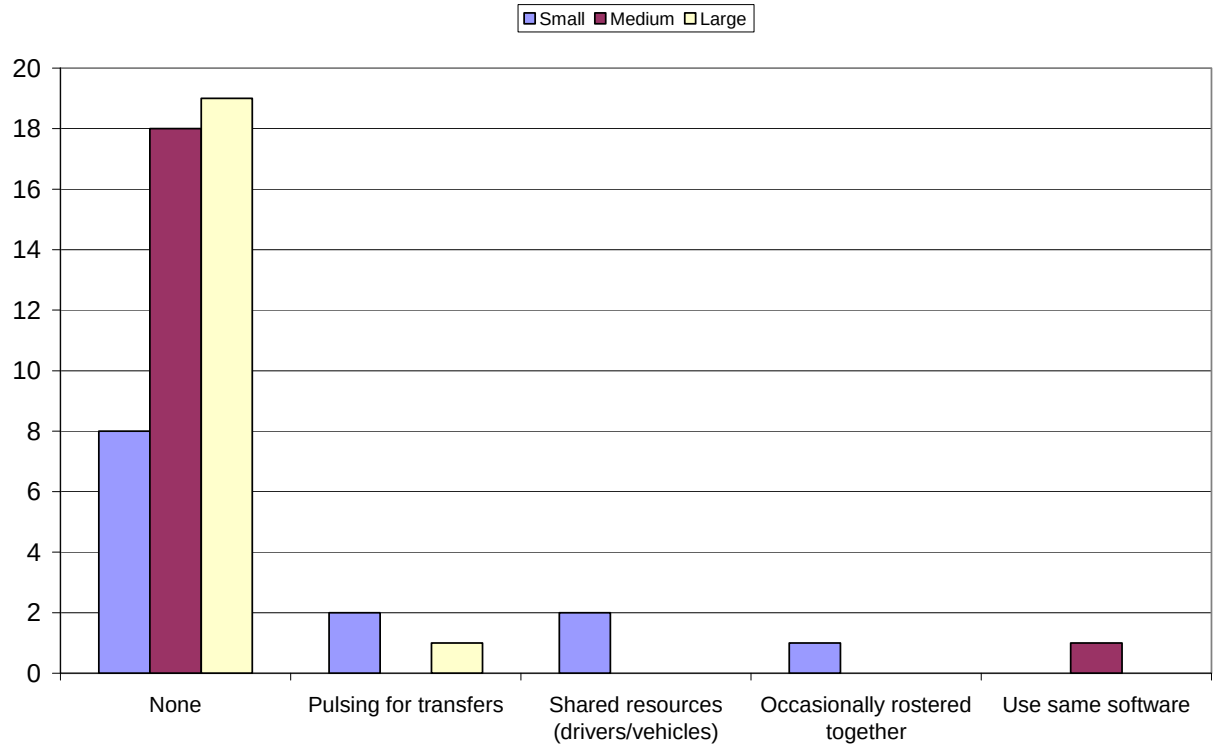
Q15. How long does the schedule creation process typically take, from concept through to implementation?



Copyright National Academy of Sciences. All rights reserved.

Although nearly all agencies operate and schedule both fixed route and paratransit service, these services are being scheduled separately, particularly at larger agencies. Almost 90 percent of respondents indicated that there is no relationship between fixed-route and paratransit scheduling. However, five of the 14 small agencies responded that they share vehicles, pulse for transfers, or occasionally roster paratransit and fixed route services together.

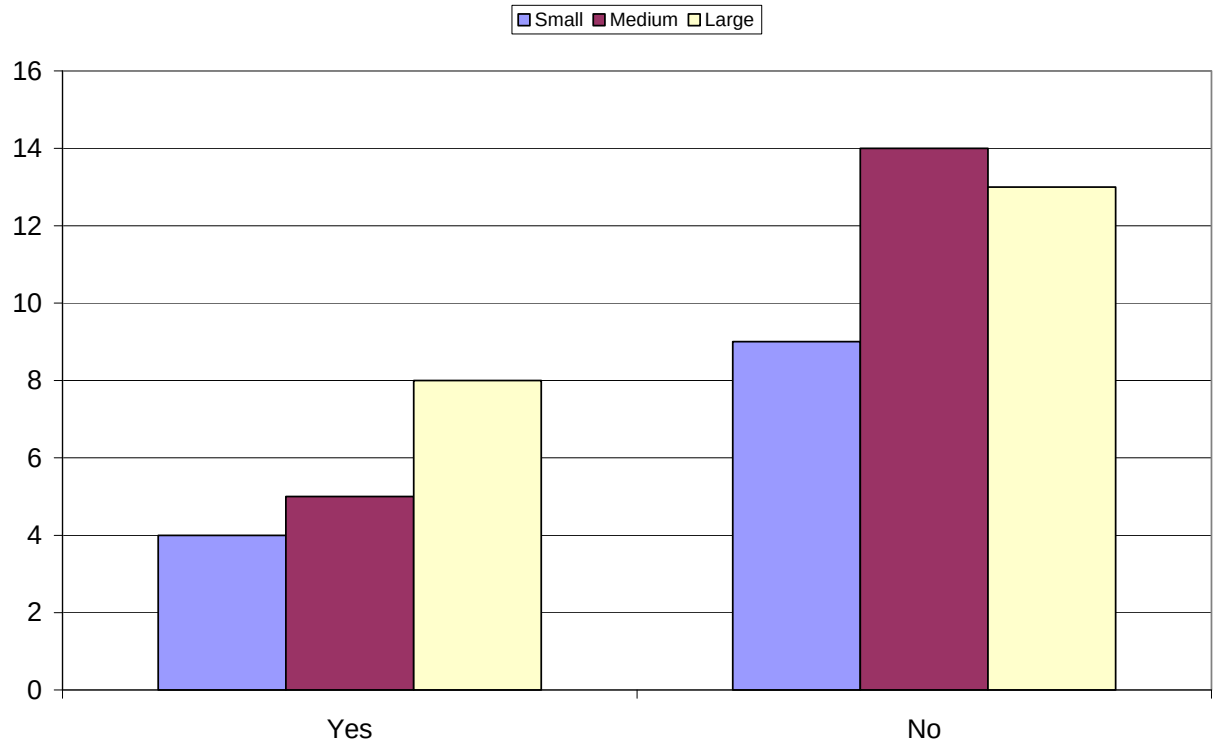
Q13. What is the relationship between fixed-route and paratransit scheduling?



Copyright National Academy of Sciences. All rights reserved.

Union review and approval is required at approximately one- third of responding agencies. The percentage was slightly higher (38 percent) for larger agencies where union representation is much more likely.

Q16. Is union review and approval required before new schedules can be implemented?



Mid-pick changes present difficulties for many transit agencies. 23 percent of respondents must have a new pick in order to enact mid-pick schedule changes, and an additional 12 percent can only change drivers' schedules by a set amount or else a new pick is required. Larger systems tend to have less flexibility make changes - half of the small agencies can make changes as needed, while only about one-third of medium and large agencies can do so.

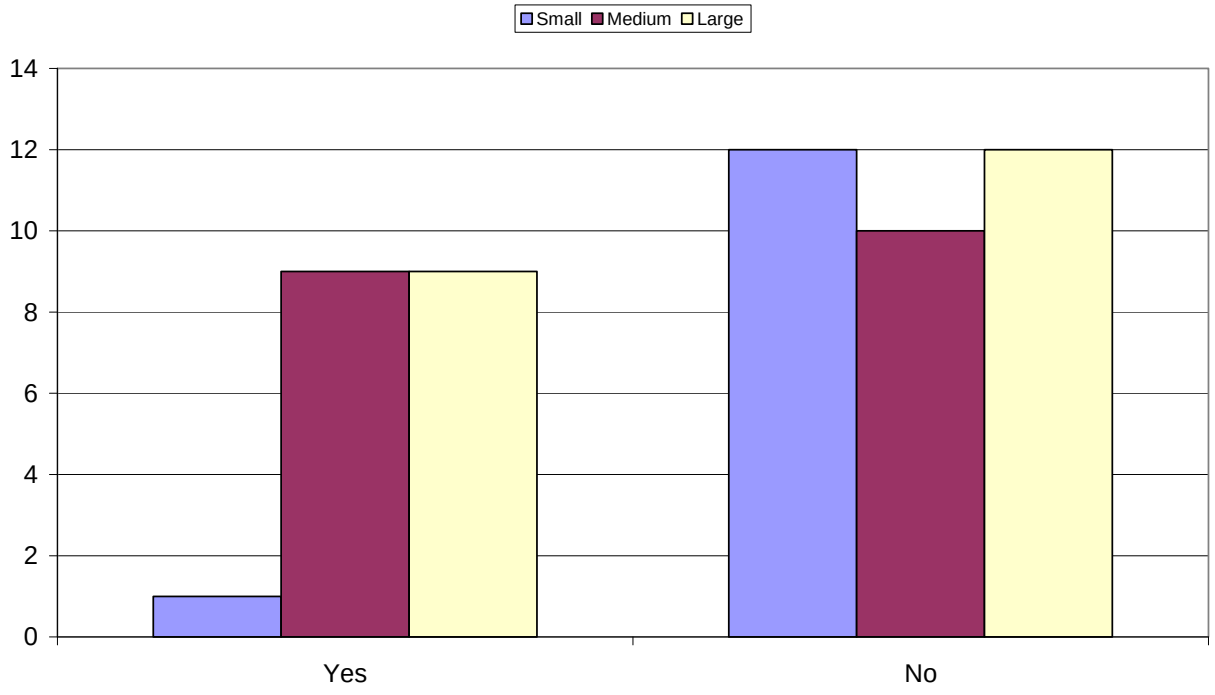
18. If bids/service change dates are fixed, what is the process for making ad-hoc scheduling changes between picks?

	Small	Medium	Large	Total	Percent
Done as-needed	5	5	6	16	37%
Agreement with Operator/Union	1	2	3	6	14%
Must not affect work picked		1		1	2%
Can only change a set amount of minutes		3	2	5	12%
Cannot be done				0	0%
Only in exceptional circumstances			1	1	2%
New pick	4	3	3	10	23%
Use extraboard or trippers		2	2	4	9%
Performed in field			1	1	2%
Changes must go to executive staff or Board		1		1	2%
				43	100%

Copyright National Academy of Sciences. All rights reserved.

Most agencies reported that exception scheduling does not account for a significant portion of the scheduling department's workload. Results are mixed for medium and large agencies, which are much more likely than smaller agencies to be involved in exception scheduling. Two-thirds of the scheduling departments that answered "yes" to this question reported that exception scheduling accounts for 30 percent or less of their time. However, two agencies (both of which operate rail service) indicated that exception scheduling accounts for over half of the scheduling department's time.

Q19. Does "exception" scheduling (i.e. preparation of temporary schedules to account for special events street closures track work or other disruptive events) account for a significant ongoing portion of the scheduling department's workload?



Copyright National Academy of Sciences. All rights reserved.

As noted in the introduction, survey responses regarding constraints that limit the efficiency of schedules are especially important. All large agencies and a majority of small and medium-sized agencies reported some unusually restrictive rules or practices. The most frequent responses included spread time limits, layover and recovery requirements, and meal break requirements. A wide variety of rules and practices were cited, as seen below.

17. Are there any unusually restrictive rules or practices at your agency?					
Category	Small	Medium	Large	Total	%
Spread limitations	2	4	1	7	16%
Layover/recovery requirements	1		4	5	11%
Meal break requirement	2	1	2	5	11%
Midpick changes restrictive	1	3		4	9%
Straight run – percentage			3	3	7%
Interline limitations		1	1	2	5%
Overtime	1	1		2	5%
Part time operator limitations			2	2	5%
Relief limitations - not after certain time		1	1	2	5%
Spread penalty		2		2	5%
Board Approval	1			1	2%
Budget			1	1	2%
Constraint on number of runs created or reduced			1	1	2%
Driver garage assignments - can't move unless route moves			1	1	2%
Hour guarantee per week	1			1	2%
Maximum number of lines per run			1	1	2%
Number of bids			1	1	2%
Preservation of union trippers		1		1	2%
Runcutting practices			1	1	2%
Swing shift limitations			1	1	2%
	9	14	21	44	

Another question asked about mode-specific scheduling practices and constraints. Rail-related responses are presented later in the rail section. Bus responses included several already mentioned, such as break requirements, limits on interlining, and other contract restrictions. Other considerations were reported, including:

- Vehicle size and type, which restrict interlining opportunities
- Meal break scheduling that results in almost half of all operators being on meal break at the same time;
- No road reliefs allowed;
- A transfer center with ten bus bays and 23 routes;
- Sharing vehicles between paratransit and fixed route services.

Copyright National Academy of Sciences. All rights reserved.

When asked to prioritize in terms of practices the agency would change if it could, 24 percent cited spread time limitations, 24 percent named break requirements, and 22 percent would change split run limitations. Restrictions on the use of part-time operators (PTOs) and daily overtime requirements were also mentioned by several respondents. Concerns over break requirements were common regardless of agency size, while split run limitations concerned larger agencies, spread time limitations and restrictions on PTOs were most common among medium and large agencies, and daily overtime was a concern of small and medium agencies.

22. Which parts of the labor agreement or scheduling practices have the greatest impact on overall scheduling efficiencies? Put another way, what would you change if you could?

	Small	Medium	Large	Total	%
Break requirement	4	3	4	11	24%
Daily overtime	2	4	1	7	16%
Days off		3	1	4	9%
Extraboard rules	1			1	2%
Forced headways			1	1	2%
Hours requirement	1	1	3	5	11%
Interlining limitations		1	1	2	4%
Layover/recovery requirement	1		4	5	11%
Mid-pick change restrictions		1		1	2%
Number of lines per run			1	1	2%
Number of picks			2	2	4%
Part time operator limitations	1	3	5	9	20%
Pay types			1	1	2%
Pulse timing		1		1	2%
Run type percentage			1	1	2%
Spread limitations	1	4	6	11	24%
Straight run - percentage	2	1	7	10	22%
Swing run limitations			1	1	2%
Straight run & split run must have same line of origin			1	1	2%
Runs not funded by federal or state money must be given to union drivers	1			1	2%
				45	

Copyright National Academy of Sciences. All rights reserved.

One survey question asked about innovative or alternative approaches to scheduling that might be of interest to other systems. Several respondents were uncertain whether particular aspects of their scheduling qualified as innovative, but shared them with us nonetheless. The most interesting feature of the responses is their wide range.

12. Does your agency use any innovative or alternative approaches to scheduling that may be of interest to other systems?

	Small	Medium	Large	Total	%
Use Computer Program	1	1	4	6	22%
Interlining	1	2	4	7	26%
Running time information available/ uploaded directly from AVL to scheduling program		1	1	2	7%
Use of part-time operators (avoid long splits)		1	1	2	7%
Flex routing in smaller communities	1			1	4%
Keep schedule tight at beginning of route; add more time at end to avoid running hot		1		1	4%
Considering fallback operators for breaks		1		1	4%
Variable shift lengths (8, 9, and 10 hr shifts)			1	1	4%
Use dayoffcalculator.com	1			1	4%
Trip scoring system to rate costs and passenger volume		1		1	4%
Decentralized schedule function			1	1	4%
Mix assignments to reduce overtime	1			1	4%
Intermediate timepoint on BRT line to control bus flow		1		1	4%
Roster AM and PM trippers in combinations for PTOs to maximize platform time			1	1	4%
Hub and spoke route network	1			1	4%
'Shift' individual trips a predetermined number of minutes early or late to reduce vehicle requirements and costs			1	1	4%
Global optimization of garage assignments			1	1	4%
Use of school bus operators for extraboard and vacation relief	1			1	4%
Special holiday schedules			1	1	4%
Involve all departments (customer service, operators, shop stewards, ops supervisors)	1			1	4%
Each scheduler performs all tasks (data analysis, schedule building, run cutting)			1	1	4%
Data collection from new developments, passengers, operators, and planning	1			1	4%
	8	10	11	27	

Copyright National Academy of Sciences. All rights reserved.

B.3 Schedule Writing

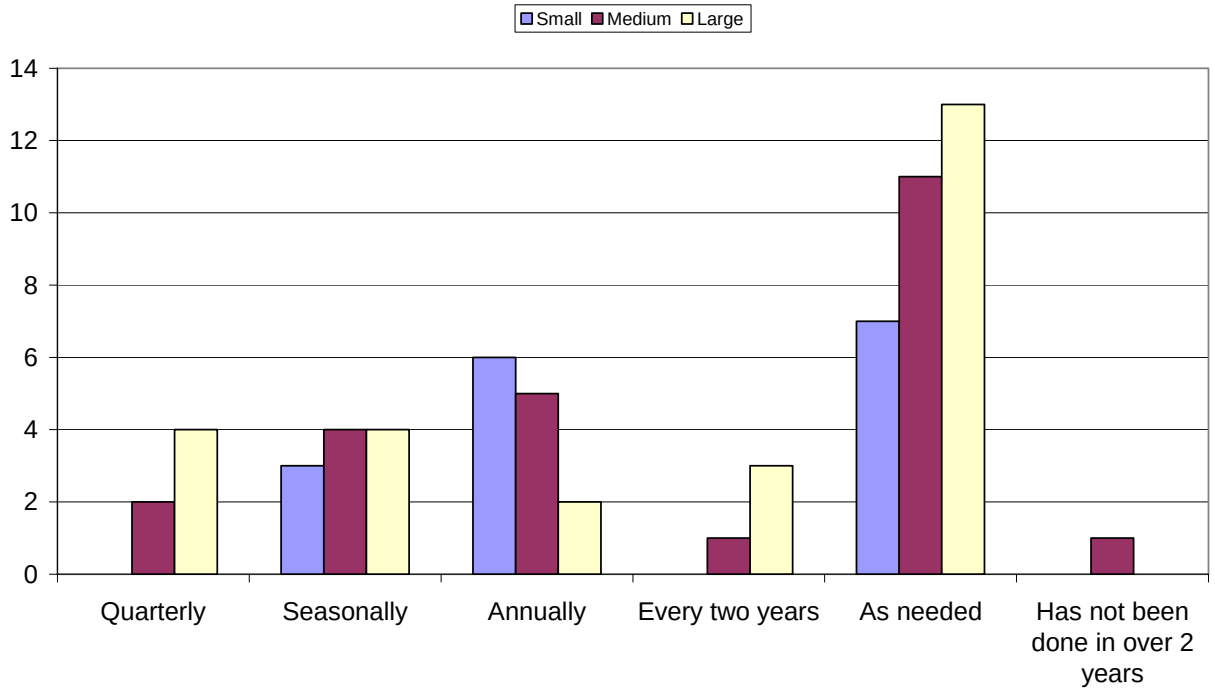
Workload and historical requirements typically determine manpower needs for scheduling departments.

Q33. How are manpower requirements for the scheduling department determined?					
	Small	Medium	Large	Total	%
Workload	8	6	5	19	39%
Historical		3	6	9	18%
No determination	3	3	1	7	14%
Budget	1	1	2	4	8%
Per division basis			4	4	8%
Revenue hours	1	1	1	3	6%
Management		1	1	2	4%
Human resources			1	1	2%
Experience		1		1	2%
Number of routes		1		1	2%
System growth		1		1	2%
				49	

Copyright National Academy of Sciences. All rights reserved.

Most agencies adjust their schedules as needed. Almost half (45 percent) review and adjust schedules at set intervals (quarterly, annually, or every two years), and many of these agencies report that they also make adjustments as needed. Seasonal changes are usually related to the school year, and may not involve a new schedule, e.g., if nothing has changed on the route, last summer's schedule may be dusted off and used.

Q52. How often are schedules adjusted on a typical route (aside from running time changes)? For the purposes of this question an adjustment is anything more than moving trips by a minute or two.

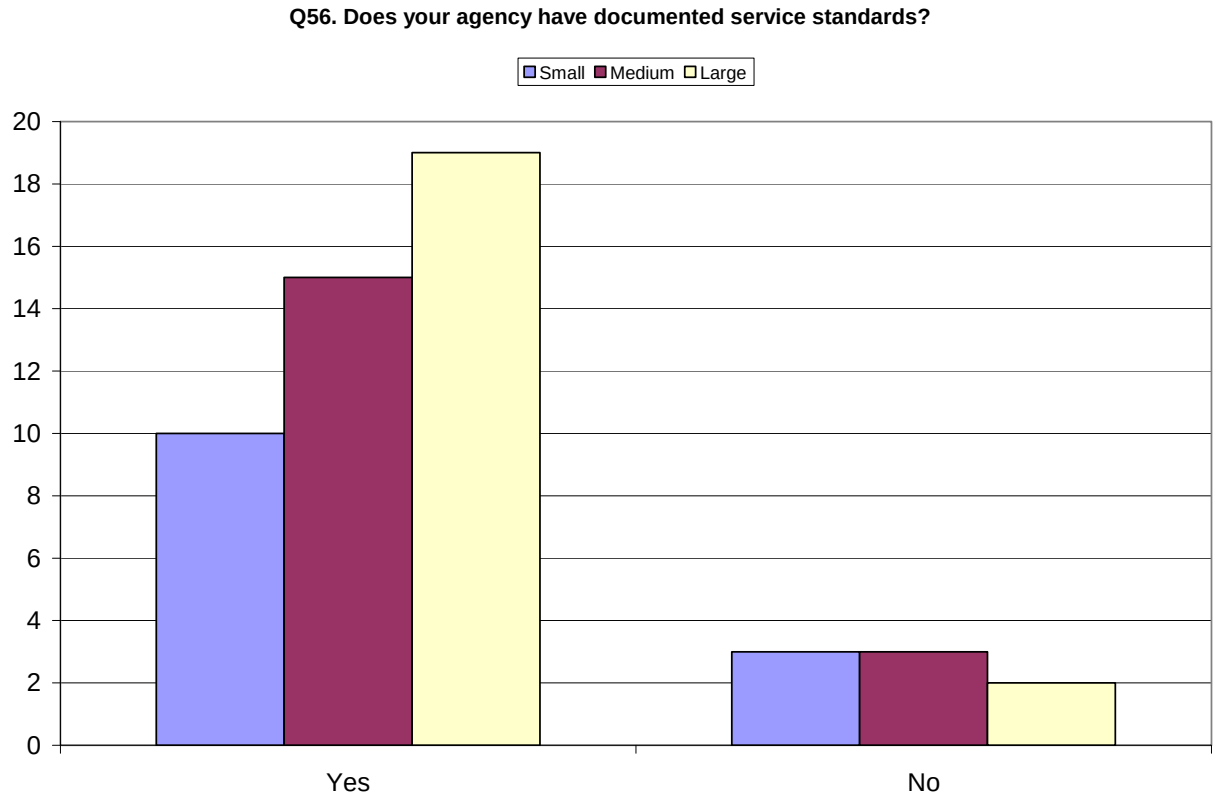


The process of new schedule development is different from agency to agency, but generally follows this path:

1. Schedulers and/or planners review and analyze ridership and running time data and prepare a new service plan (outside input may come from the public, operators, supervisors, and the union)
2. Senior management, the public and/or the board reviews the service plan
3. Schedulers block trips
4. Schedulers cut runs
5. Schedulers roster
6. Senior management reviews and approves the schedule (the union may also review and/or approve)
7. The agency implements the new schedule.

Copyright National Academy of Sciences. All rights reserved.

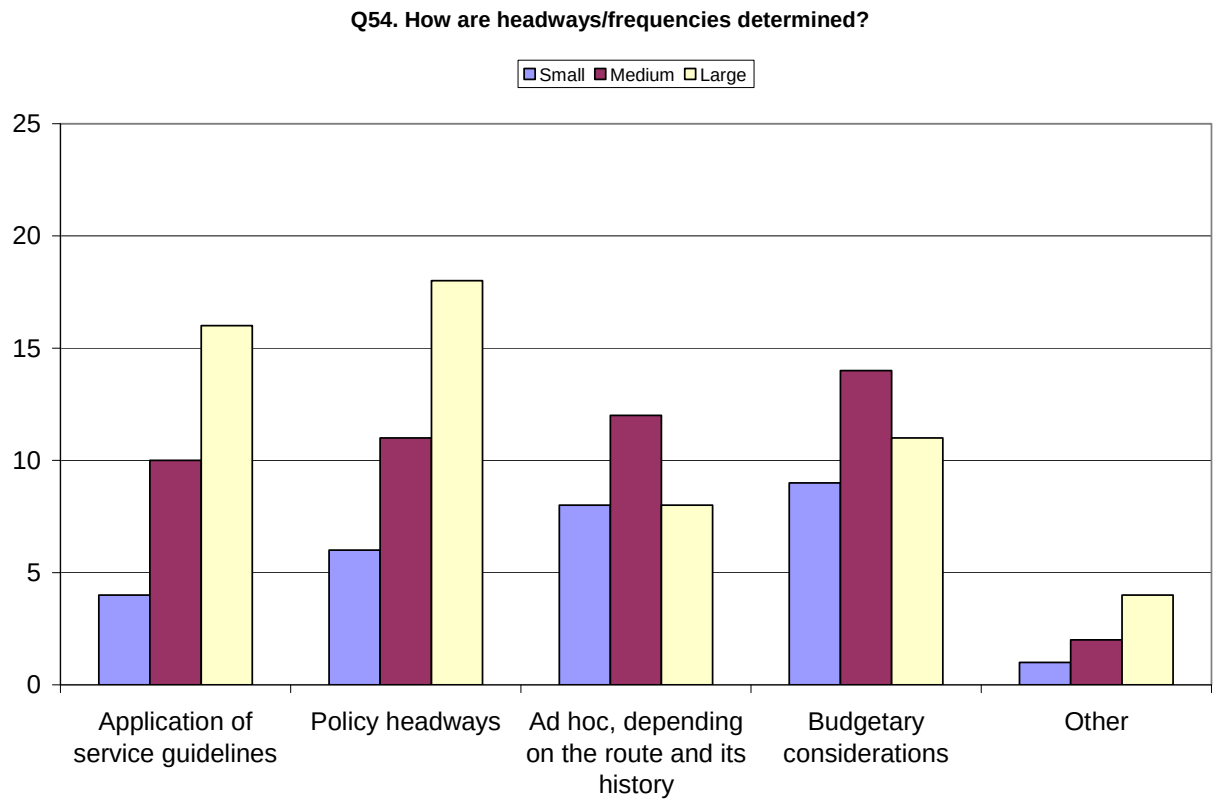
Most agencies (85 percent) have documented service standards that are used in the development of service plans (step one). Small agencies are somewhat less likely to have service standards (77 percent, versus 83 percent of medium and 91 percent of large agencies).



Service standards are usually oriented toward productivity (e.g., riders per revenue hour) or peak load factor (passengers on board per trip at the peak load point). Agencies use either APC or ridecheck data in the application of the service standards, and also take the capacity of the vehicle into consideration. One agency has its load factor dictated by judicial fiat.

Copyright National Academy of Sciences. All rights reserved.

Agencies frequently use multiple means to determine service frequency on a given route. Agency policies may call for either clockface headways or a minimum frequency regardless of demand. Budgetary considerations are always a consideration, but perhaps do not rank as highly as might have been expected. Application of service guidelines is common. An ad hoc approach, depending on the route and its history, may also be used. Each of these four factors was cited by at least half of all survey respondents.

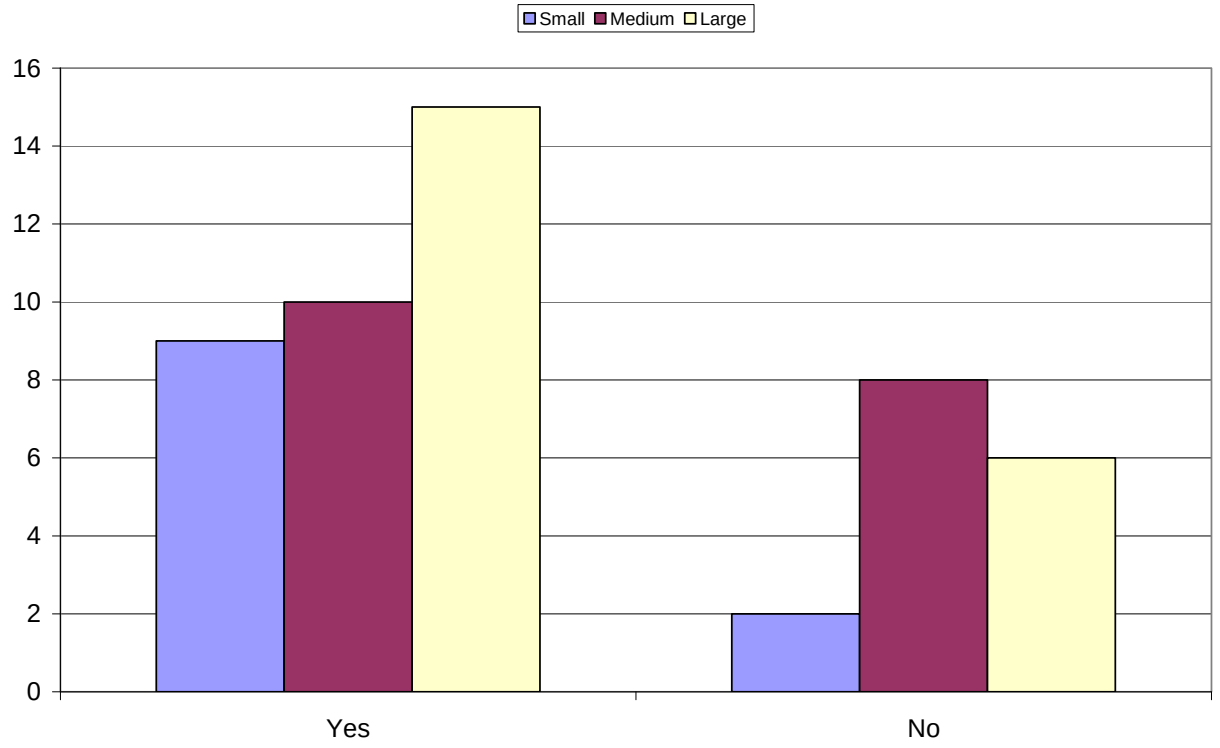


In the typical process for schedule development cited above, schedulers are given desired routing and service levels. It is not clear whether schedulers have the opportunity to provide feedback regarding inefficiencies resulting from a specified frequency of service on a particular route. Closing the loop through scheduler feedback is critical, because service frequency is a major factor influencing the number of operators/vehicles and cost required for a given route.

Copyright National Academy of Sciences. All rights reserved.

Clockface headways are considered important at approximately two-thirds of responding agencies. The percentage was much higher at small agencies (82%) where service is likely to be less frequent. In a follow-up question, the frequency at which clockface headways are unnecessary was cited at six to 10 minutes or less by over half of all respondents and at 12 to 15 minutes or less by an additional one-quarter of respondents.

Q59. Are clockface headways considered important at your agency?



Communicating schedule information to the public is important. The majority of agencies (75 percent) provide times at all published timepoints, and another 20 percent provide either times or general headways, depending on the frequency of service. The remaining agencies publish only general headways. Approximately 30 percent of all agencies produce and publish timetables for each stop, to be posted at the stop. Large agencies are somewhat more likely to take this approach (45 percent of large agencies). Times between timepoints are most often extrapolated by distance, by average system speed, or by a software package.

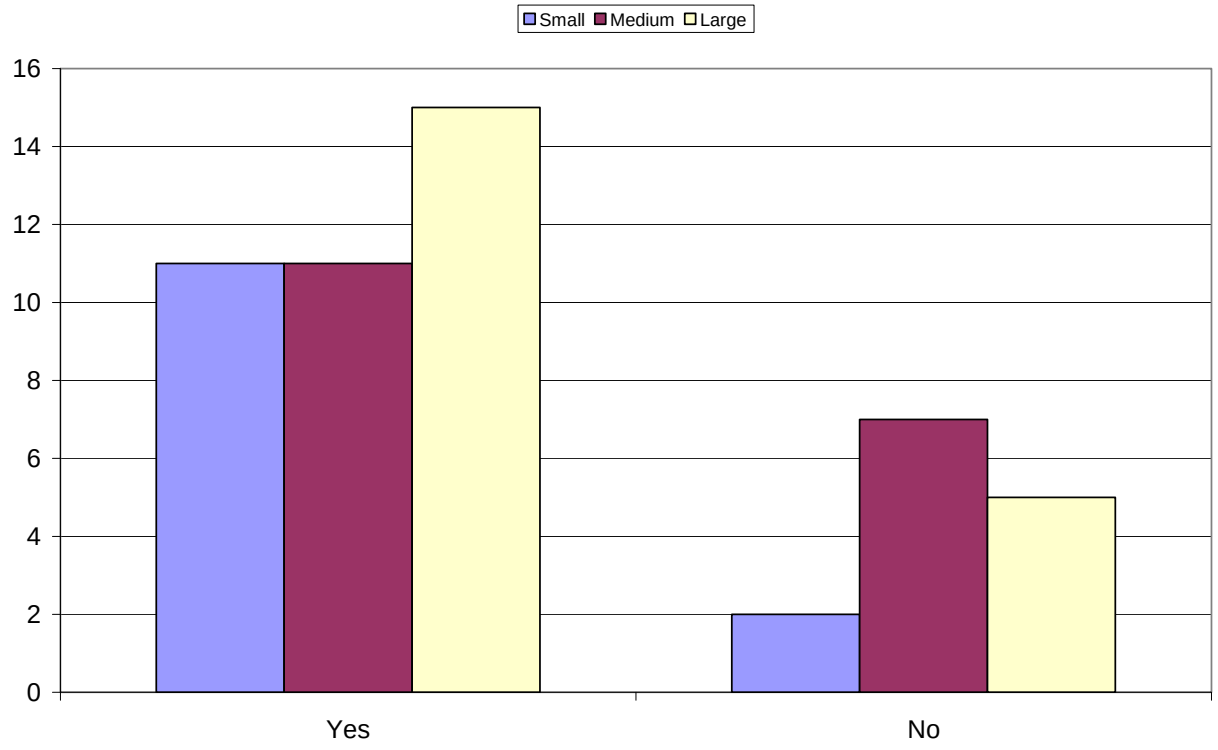
The remainder of this section presents results regarding other factors that affect schedule writing, such as different types of service, timed transfers, school open/closed, intertiming along trunk segments, and effects on other elements of scheduling.

Over 80 percent of all respondents operate express, limited-stop, or skip-stop service. These services are very common among medium and large agencies, but the majority of small agencies (63 percent) do not operate these services. Over two-thirds of agencies reported no difference in how schedules are prepared for express service other than faster run times. Differences reported by other agencies included free running time once the bus was on the highway, demand-based schedules, different service standards, and the need to build express schedules around employer shift times.

Copyright National Academy of Sciences. All rights reserved.

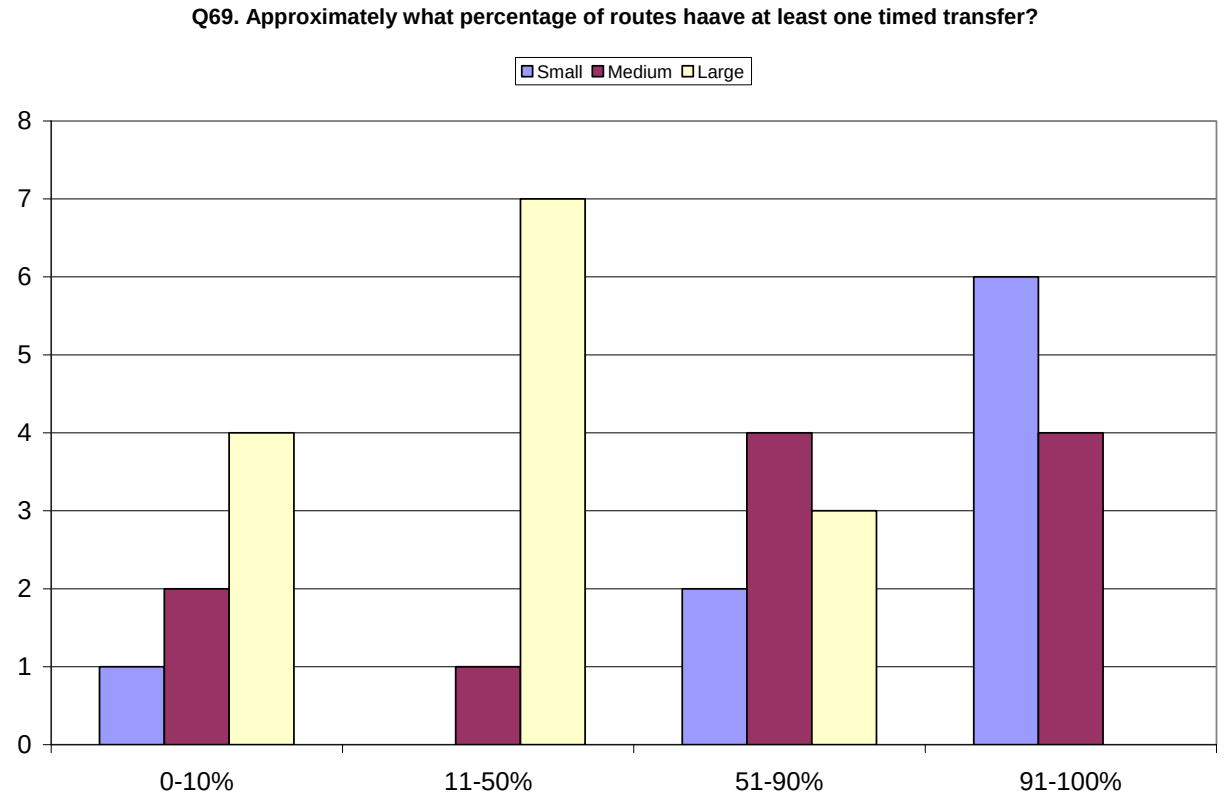
Timed transfers are an established feature of transit systems: 73 percent of respondents report the use of timed transfers. Among agencies that use timed transfers, almost three-quarters indicated that intermodal as well as bus-to-bus transfers are timed.

Q66. Does your agency operate timed transfer locations either bus or multimodal?



Copyright National Academy of Sciences. All rights reserved.

Agencies tend to have either a low or high percentage of routes with at least one timed transfer. This indicates an "all or nothing" approach to timed transfers, i.e., it is either an overarching agency policy or it is done on a minimal or location-specific basis. At 29 percent of all agencies responding, over 90 percent of their routes have at least one timed transfer. Two-thirds of small agencies indicated that over 90 percent of their routes have timed transfers. Typically, small agencies have a radial structure with a single hub in downtown. At the other extreme, 21% of agencies reported that only ten percent of their routes or less have a timed transfer. Large agencies, with higher service frequencies and a denser service network, were less likely to have a high percentage of routes with timed transfers.

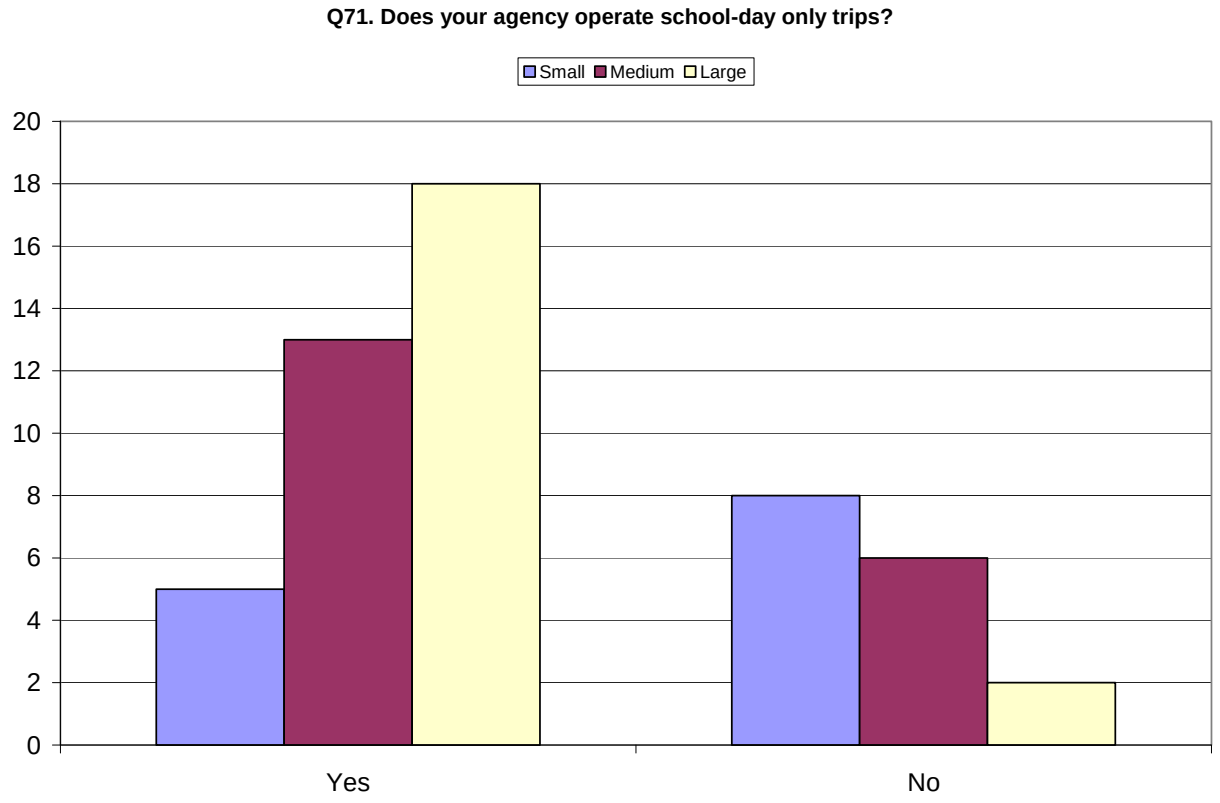


A central issue for schedulers regarding timed transfers is the size of the transfer window at timed transfer locations. The overwhelming majority of respondents (93 percent) reported a window of five minutes or less, with 68 percent of respondents specifying five minutes as the window. Interestingly, there does not appear to be variation to allow for walking distance between stops at transfer locations or time-of-day-specific reliability. Rather it is all built in to the generic 5-minute window.

Some agencies reported that drivers are instructed to wait at transfer locations via paddle notes; this is more common in the evening or on the last trip (where headways are longer and reliable connections more critical). The window for intermodal transfers was shorter than for bus-to-bus transfers at three agencies and longer at two agencies. Finally, two agencies indicated a policy of splitting the headway at transfer points (either bus-bus or bus-light rail) to avoid holding buses, ensure that the transfer can take place if the bus is late, and minimize waiting time for passengers. This approach assumes reasonably frequent service levels.

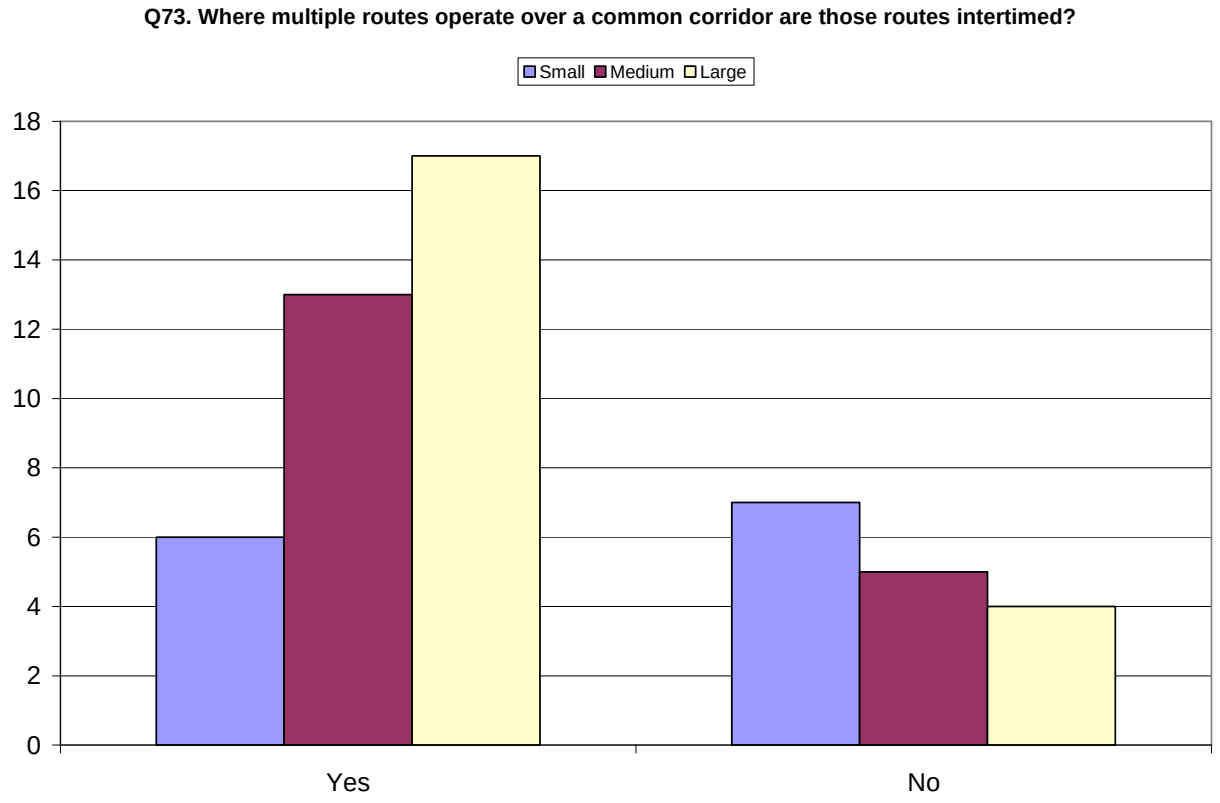
Copyright National Academy of Sciences. All rights reserved.

Over two-thirds of agencies operate school day only trips, ranging from 38 percent of small agencies to 90 percent of large agencies. Most of the agencies operating school-day service (72 percent) adjust blocks and runs on non-school days. This can have significant implications on the complexity and volume of scheduling undertaken at an agency.



Copyright National Academy of Sciences. All rights reserved.

Nearly 70 percent of respondents reported that they intertime multiple routes operating in a single corridor. The most common reason not to intertime routes is if a timed transfer is involved at one end of or along the corridor. This may explain why the majority of small systems do not intertime routes.



Consideration of subsequent scheduling tasks is very common in writing schedules. Almost 90 percent of respondents indicate that schedules are written to ensure that they can be linked effectively into blocks. This represents sound scheduling practice.

Copyright National Academy of Sciences. All rights reserved.

Survey responses regarding constraints and other influencing factors on various aspects of scheduling are especially important. Agencies most often reported demand, timed transfers, class times, budget, and vehicle capacity as factors affecting headway and schedule development. Several other factors also drew attention.

58. Please describe any other factors that influence headway and schedule development.					
	Small	Medium	Large	Total	%
Class/bell times	2	1	3	6	18%
Clockface headways			2	2	6%
Coverage			1	1	3%
Cycle time	1	1	1	3	9%
Demand	2	1	4	7	21%
Driver Comment			1	1	3%
Density			1	1	3%
Community input		1	1	2	6%
Governing body			1	1	3%
Timed transfers	2	3	2	7	21%
Budget		3	1	4	12%
Fleet availability		2	1	3	9%
Personnel constraints			1	1	3%
Season	1		1	2	6%
Vehicle capacity	2	1	1	4	12%
Demographics	2	1		3	9%
Funding source		1		1	3%
Traffic	1	1		2	6%
				34	

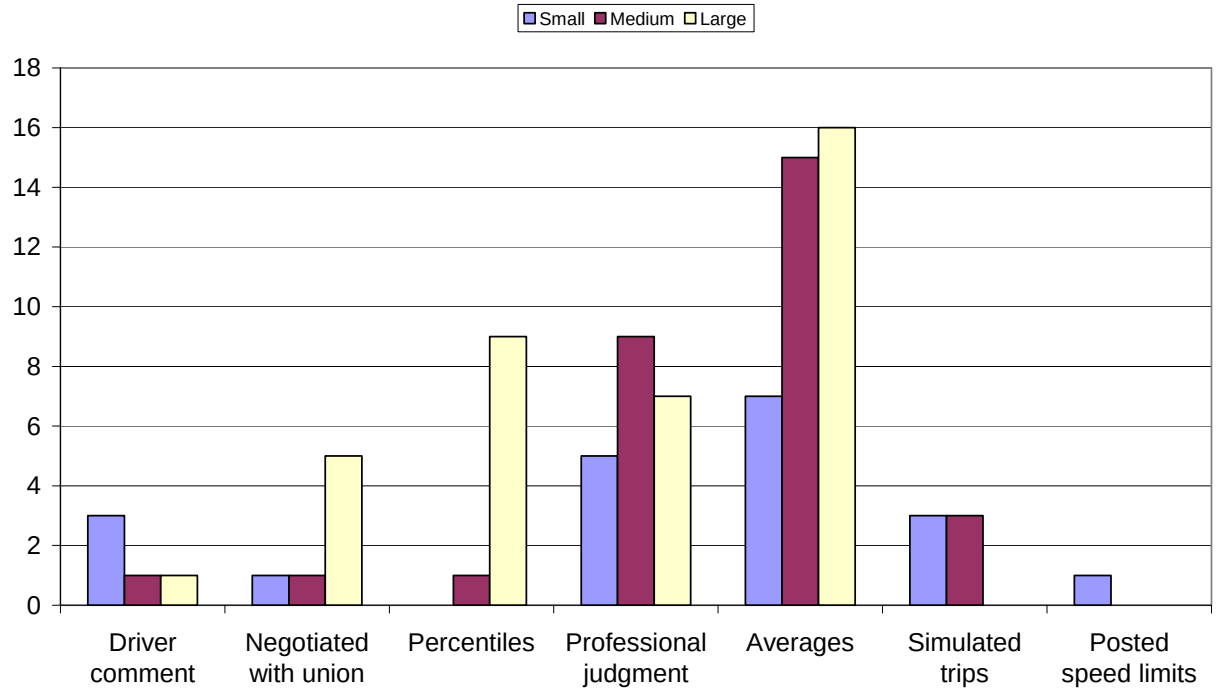
Copyright National Academy of Sciences. All rights reserved.

B.4 Running Time and Layover/Recovery Time

Running Time

One of the principal challenges that a scheduler faces is to establish “optimal” running times on route segments. Survey results indicate that almost 80 percent of responding agencies use simple running time averages, often leavened with professional judgment. Large agencies are much more likely than others to use percentiles in calculating running time. For example, one agency‘s goal is that 65 percent of trips arrive on time for the next trip and be entitled to the full layover/recovery time and 90 percent arrive on time for their next trip. Driver comments and union negotiation were mentioned as factors by one-quarter of respondents, but a follow-up question revealed that operators have the opportunity to participate in the process used to determine running times at 86 percent of responding agencies (over 90 percent of small and large agencies, 78 percent of medium agencies). Despite exponential increases in data availability and processing power, running time analysis methods still tend to be simple. Some reasons for this are discussed later in the section, but running time analysis is an important area to address in the scheduling manual.

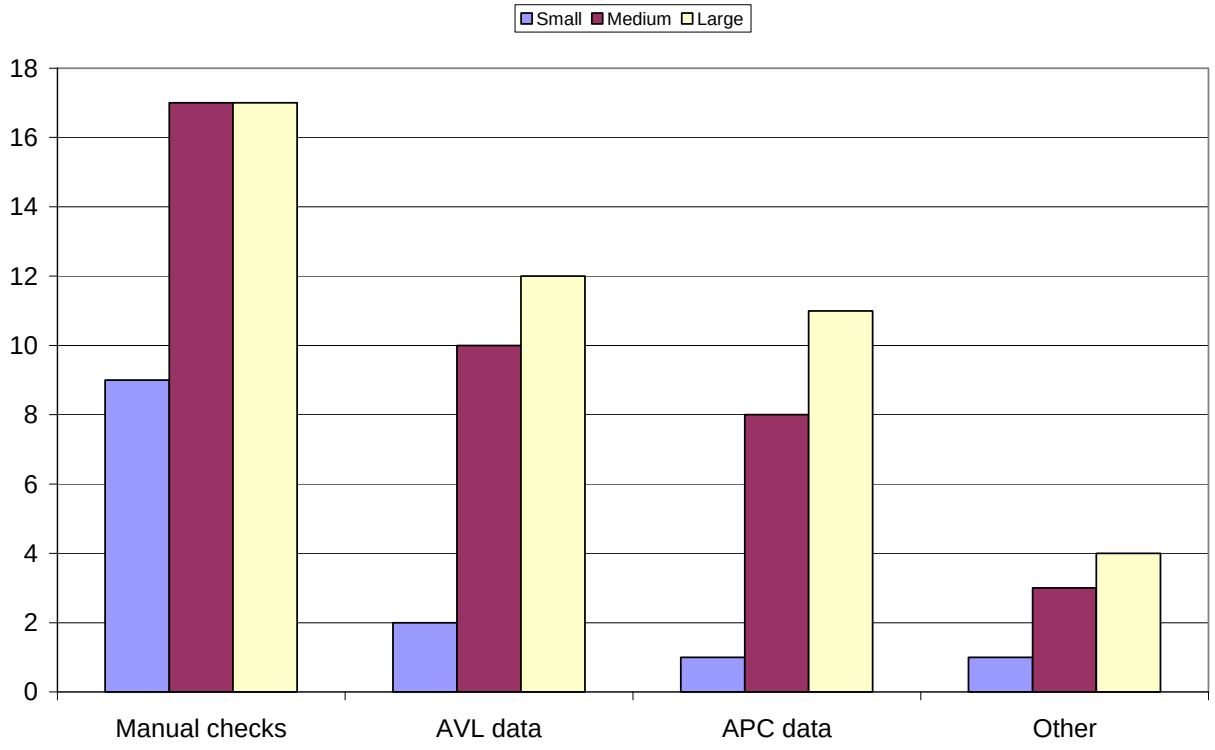
Q79. Describe, in summary form, your agency's approach to calculating appropriate running times (e.g., use of averages, a certain percentile, professional judgement, negotiation with unions).



Copyright National Academy of Sciences. All rights reserved.

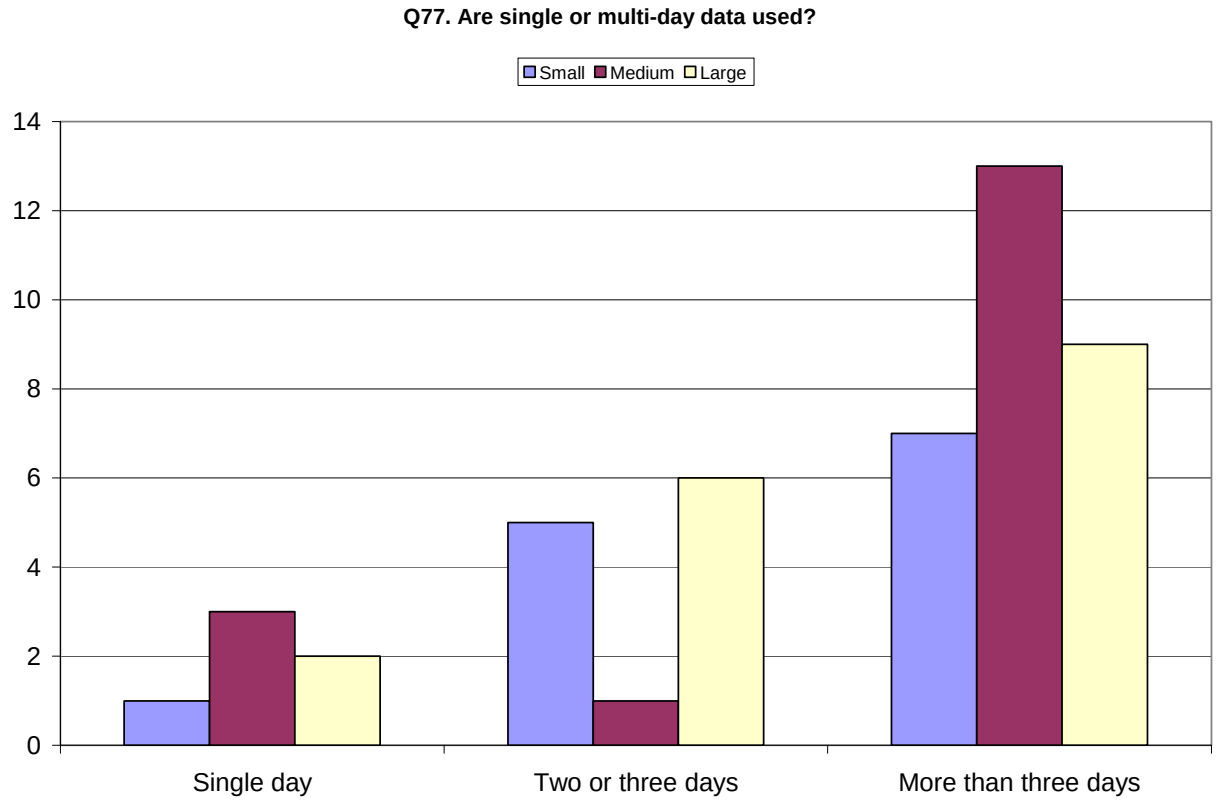
Almost half of participating agencies collect running time data on a typical route daily, due largely to the increased prevalence of new technologies like AVL and APC. The percentage of large agencies collecting the data daily was slightly lower at only 39 percent. Despite the inroads of new technology, 86 percent of respondents still use manual checks as one means to collect running time data. AVL and APC systems are each used by between 40 and 50 percent of agencies, but use of AVL and APC technologies is uncommon among small agencies. Not surprisingly, small agencies rely predominantly on manual data checks as their primary source of running time data.

Q76. What sources of running time data are available?



Copyright National Academy of Sciences. All rights reserved.

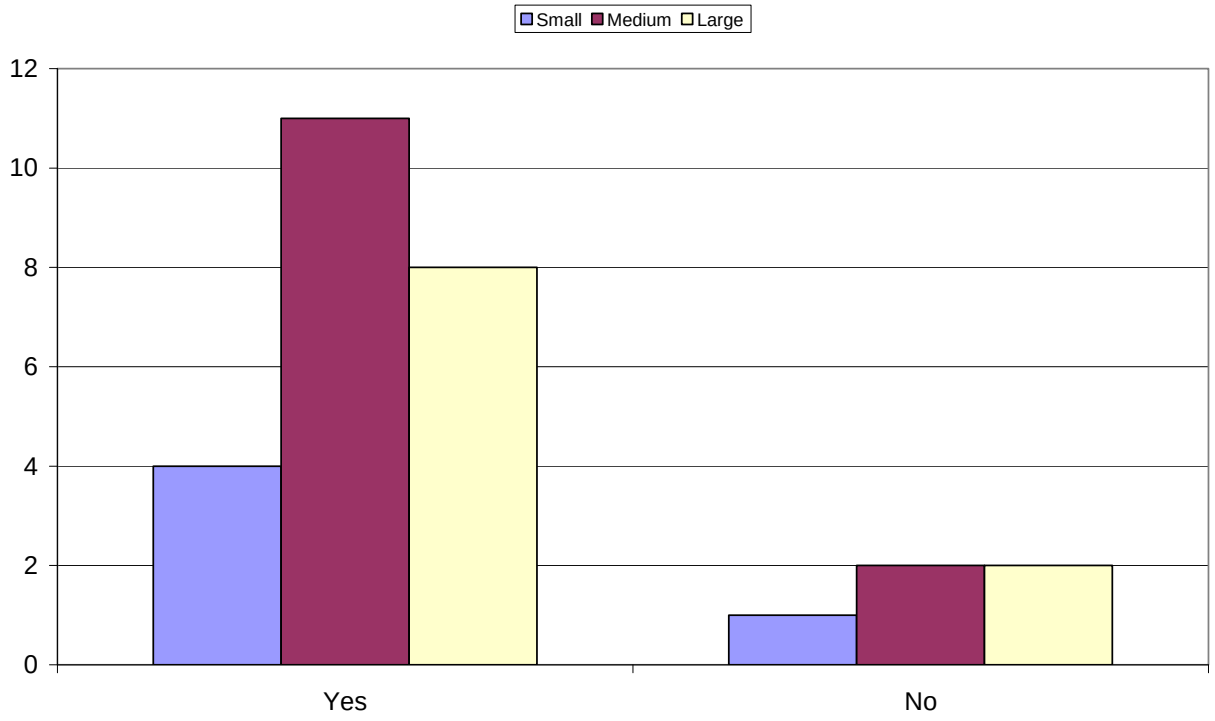
Most agencies use more than three days worth of data to calculate running times. Continuous data collection by APC and AVL systems makes it much easier to collect data over several days.



Copyright National Academy of Sciences. All rights reserved.

Among agencies using APC or AVL data, 82 percent reported that its use has improved reliability of service by providing more accurate (through multiple observations) and timely running time and on-time performance data. Agencies that did not report an improvement cited lack of staff to conduct additional analysis, lack of staff training, inflexible report formats, and lack of reliable departure time data through APCs.

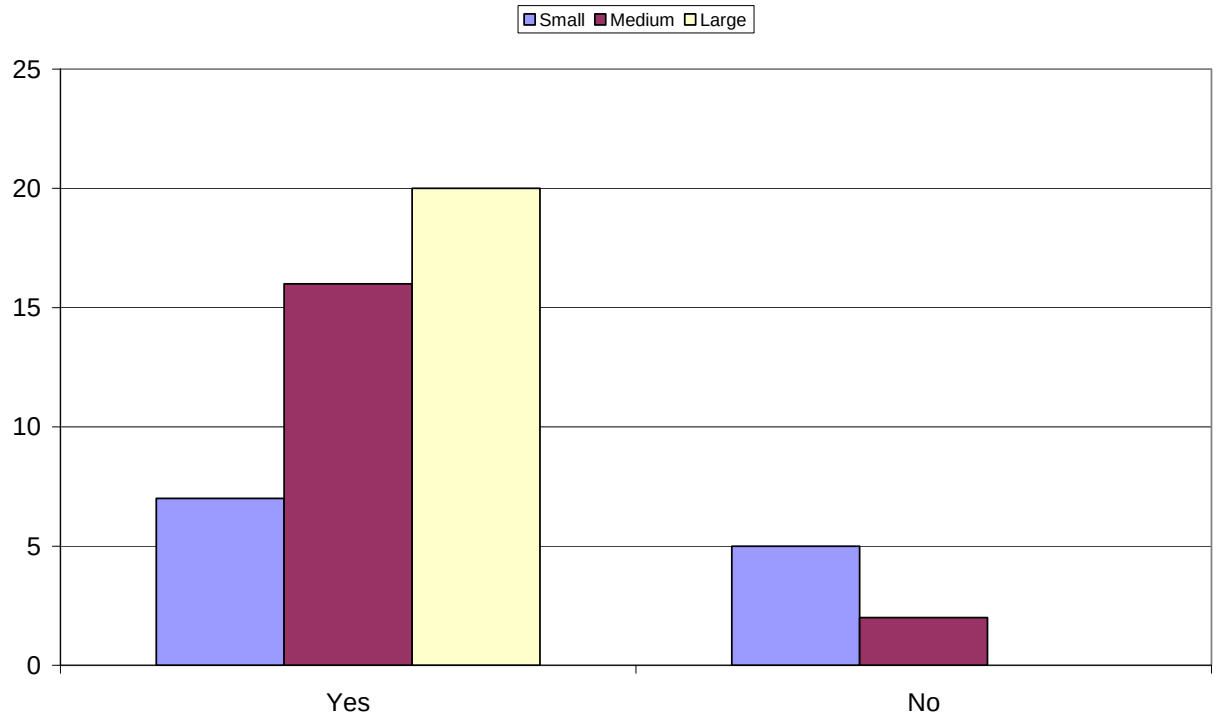
Q93. Has the advent of automated data improved the overall reliability of your services (through improved ability to update running times)?



Copyright National Academy of Sciences. All rights reserved.

Most agencies (86 percent) change running times throughout the day and/or on weekends. All large agencies reported doing this, but small agencies are less likely to vary running times throughout the day (i.e., have a standard all-day running time).

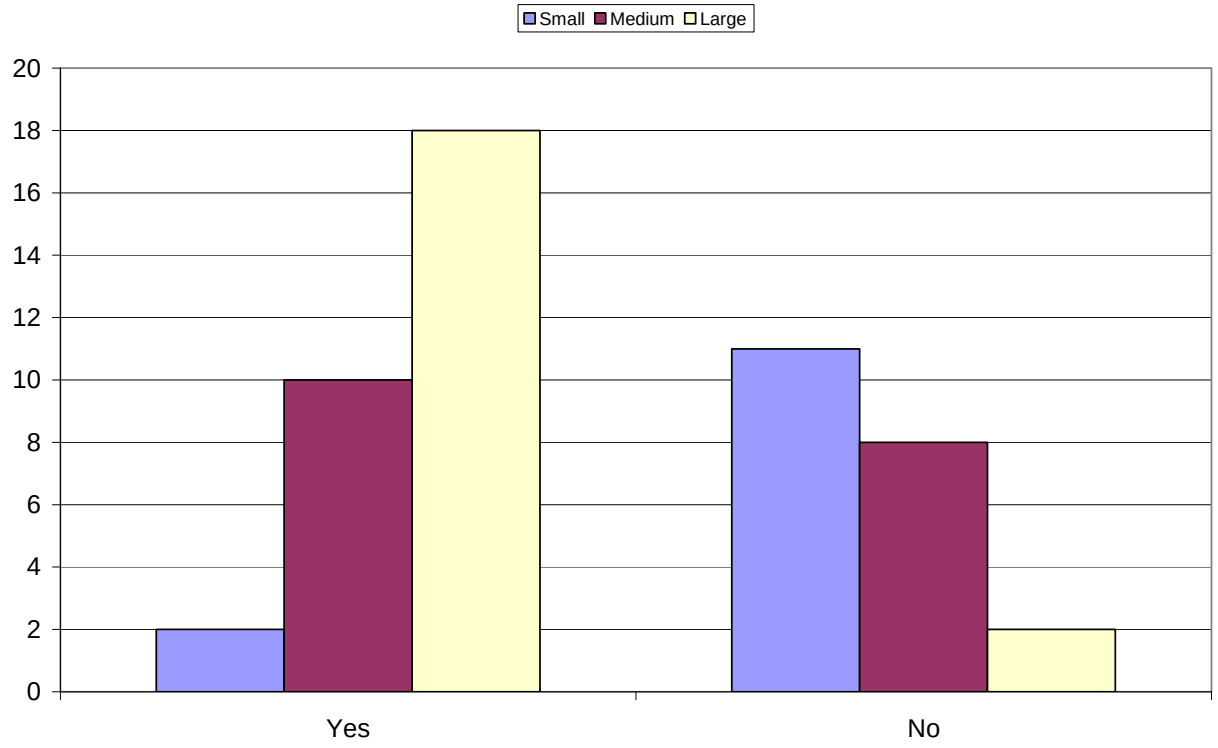
Q85. Does your agency use different running times at different times of the day and on different days of the week?



Copyright National Academy of Sciences. All rights reserved.

Route length is a factor affecting running time reliability, according to 59 percent of responding agencies. Longer routes show a trend towards greater variability and lower reliability in these systems, presumably because on longer routes there are more opportunities for things to go wrong. Large agencies were more likely to mention the trend, while only 15 percent of small agencies reported less reliability on longer routes.

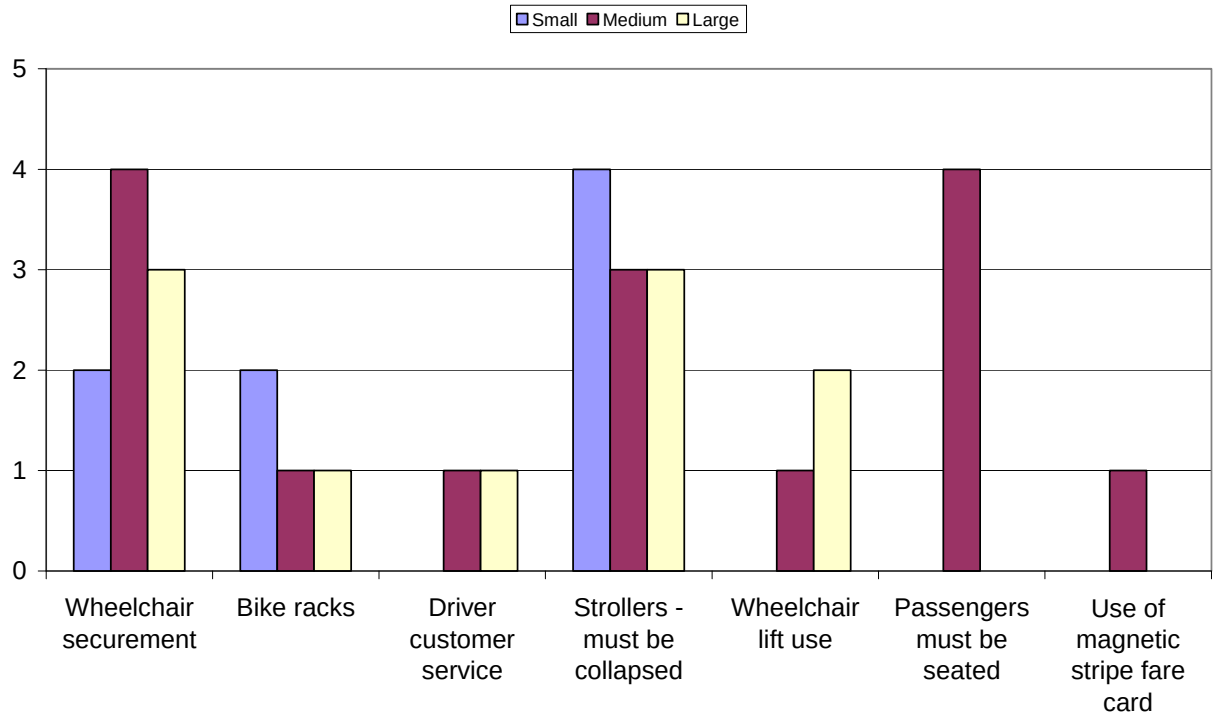
Q92. Do longer routes show trends towards less reliability on running time at your agency?



Copyright National Academy of Sciences. All rights reserved.

Running time is not only affected by traffic congestion and ridership. System policies and vehicle type can influence dwell times. Most agencies (62 percent) reported that system policies do not affect dwell time. At least half of the agencies that see an influence cited stroller or wheelchair securement as affecting dwell time. A more unusual policy mentioned by four medium sized agencies stated was the requirement that passengers must be seated before the vehicle departs the stop. Often this type of policy exists where less mobile passengers (possibly seniors, for example) form the bulk of ridership. The survey did not ask whether agencies consider tradeoffs between liability/risk and operating costs in setting these policies.

Q81. If any system policies (folding strollers, all seated passengers, or others) affect dwell time?



Copyright National Academy of Sciences. All rights reserved.

One-third of responding agencies indicated that vehicle type affects dwell time. A majority of responding agencies noted that low-floor buses reduce dwell time, particularly for wheelchair passengers. The two dissenting views regarding the impact of low-floor buses mentioned passenger tendencies either to stand toward the front of the bus, thus creating congestion in the aisle, or to wait until the bus comes to a full stop if seated up in the rear portion. Four agencies stated that articulated buses have longer dwell times while only one cited faster service with these vehicles.

83. If vehicle type (e.g., double-deckers, low-floor buses) affects dwell time at your agency, please elaborate.

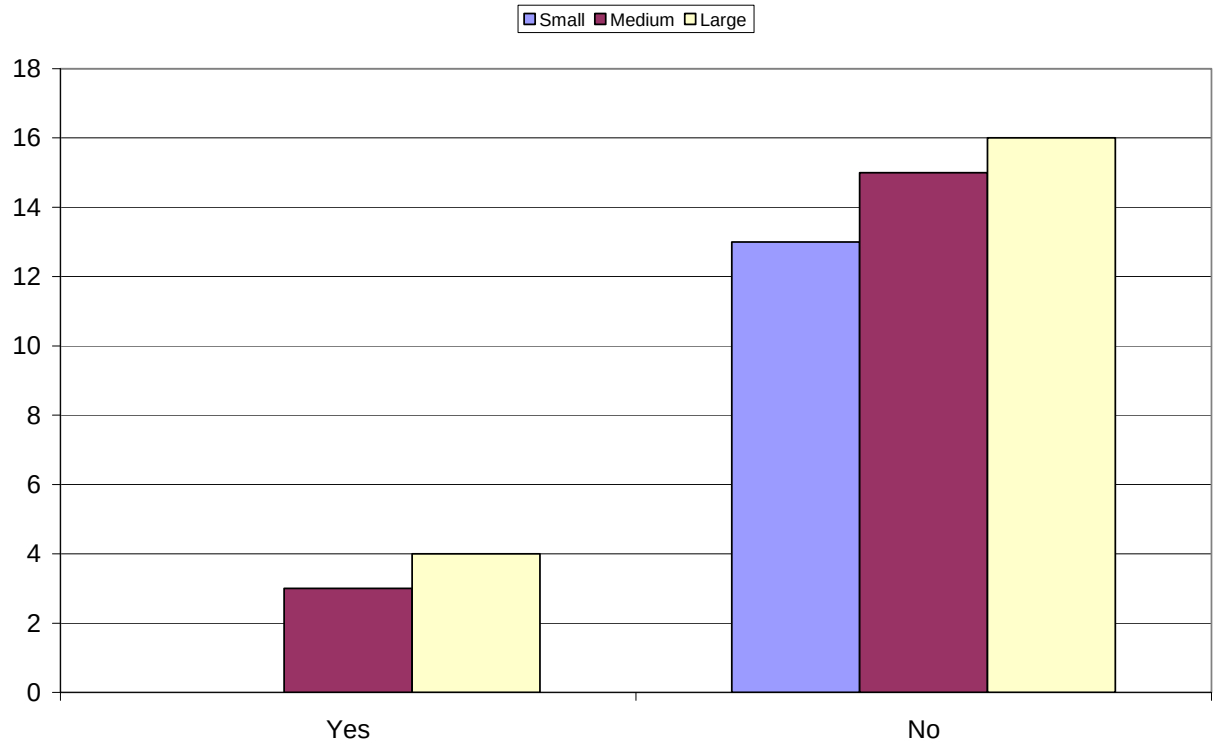
	Small	Medium	Large	Total	%
Articulated buses - longer dwell/longer to load		1	3	4	21%
Double deck buses - longer dwell/longer to load			1	1	5%
Express buses (1 door only) - longer dwell/longer to load			3	3	16%
Articulated buses - shorter dwell			1	1	5%
Low floor - shorter dwell time	4	5	2	11	58%
Low floor - longer dwell time		2		2	11%
High floor - longer dwell time		1		1	5%
				19	

Copyright National Academy of Sciences. All rights reserved.

Layover and Recovery Time

Layover time is used to allow vehicle operators a break from driving. Recovery time is built into schedules in order to help ensure that routes can start their next run on time if behind schedule. While there are subtle differences between layover and recovery time, most agencies do not distinguish between the two.

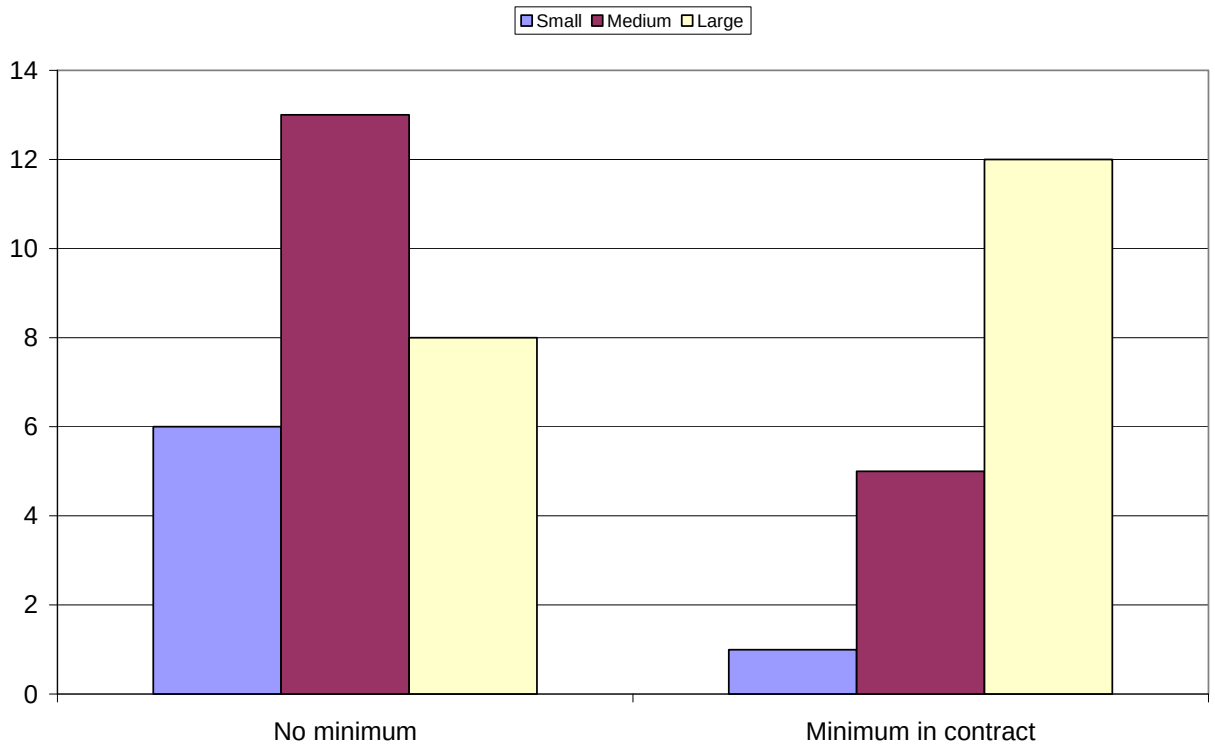
Q91. Does your agency distinguish between layover time and recovery time?



Copyright National Academy of Sciences. All rights reserved.

Sixty percent of respondents do not have a minimum layover prescribed in their labor contract. Large agencies are much more likely to have prescribed minimum layovers. The minimum layover requirement is difficult to summarize because it can be expressed as a percentage of running time, as a set number of minutes, or as both. The most common minimum reported was 10 percent of running time. Some agencies reported three minutes or five minutes as the minimum, but this could be per one-way trip or per round trip. Other reported minimums included: 10 percent or eight minutes, whichever is greater; 15 percent or seven minutes, whichever is greater; four minutes at the end of each trip, with at least seven percent of round-trip running time. Several agencies indicated that they use a minimum in constructing schedules based on general approach or past practice even though there is no contractual requirement.

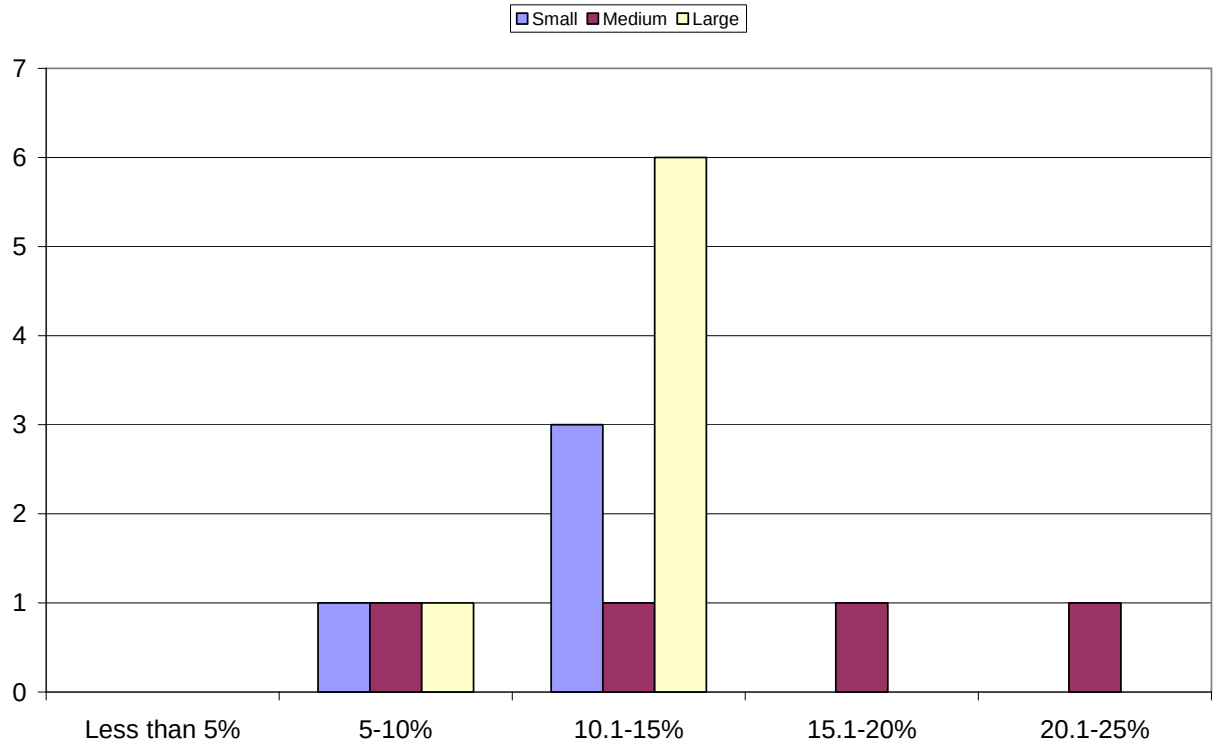
Q86. Is there a minimum layover prescribed by labor contract rules?



Copyright National Academy of Sciences. All rights reserved.

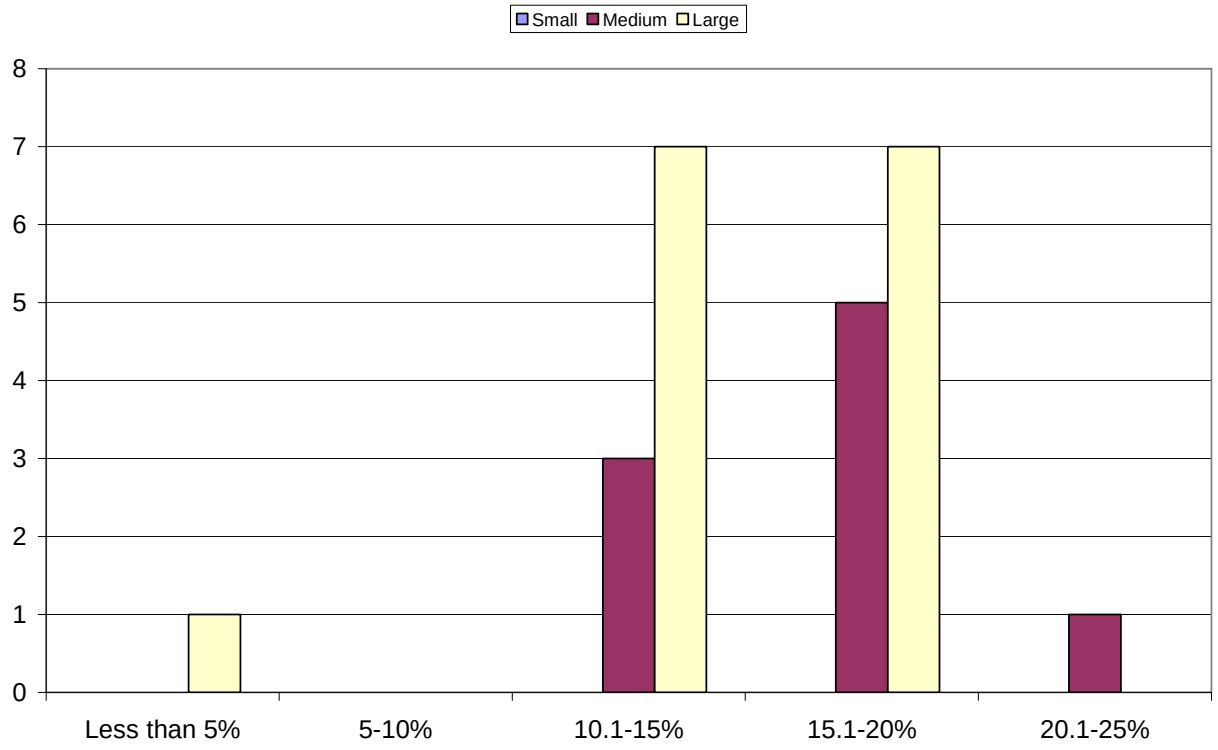
Respondents reported layover time as a percentage of platform time and of total in-service time, either overall or by day of the week. By day of week, layover time typically accounted for 10 to 20 percent of platform time on weekdays and 10 to 25 percent on weekends. Those agencies reporting overall percentages fell in the range of five to 15 percent. Layover accounted for a higher percentage of in-service time, but followed a similar trend by day of the week.

Q105. Overall, what is the layover as a percentage of platform time at your agency?

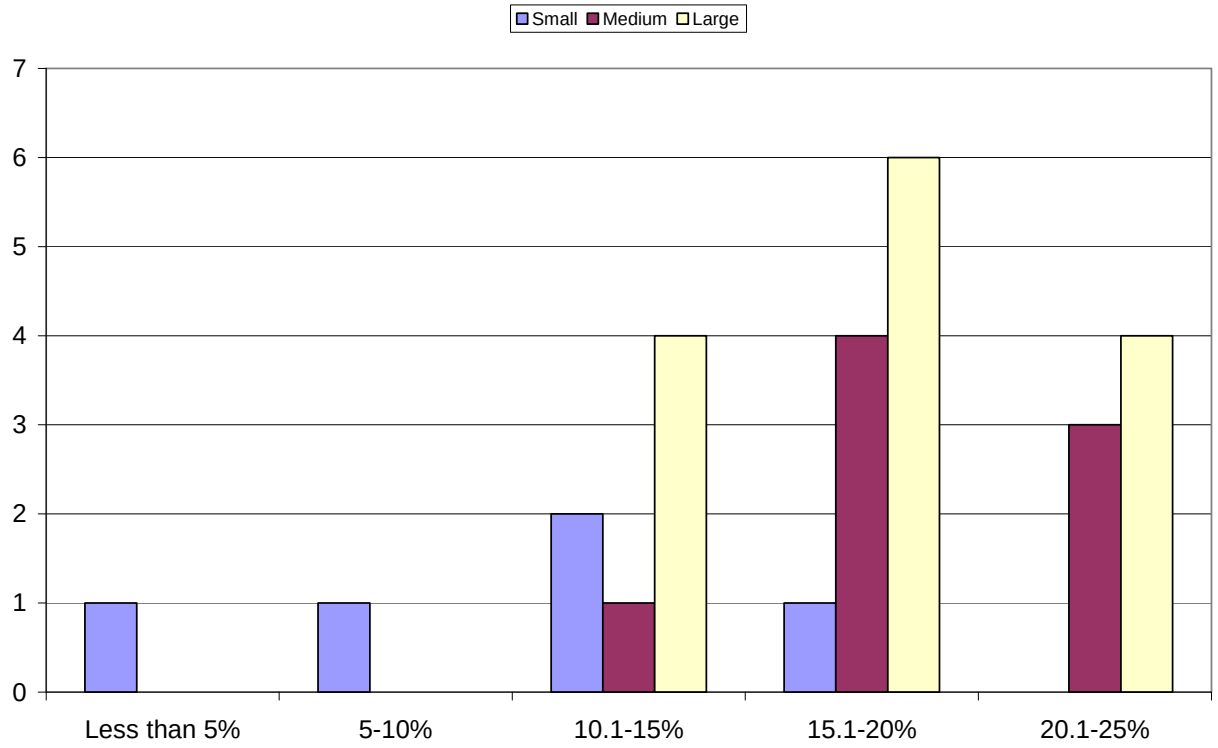


Copyright National Academy of Sciences. All rights reserved.

Q105. What is *weekday* layover as a percentage of platform time at your agency?

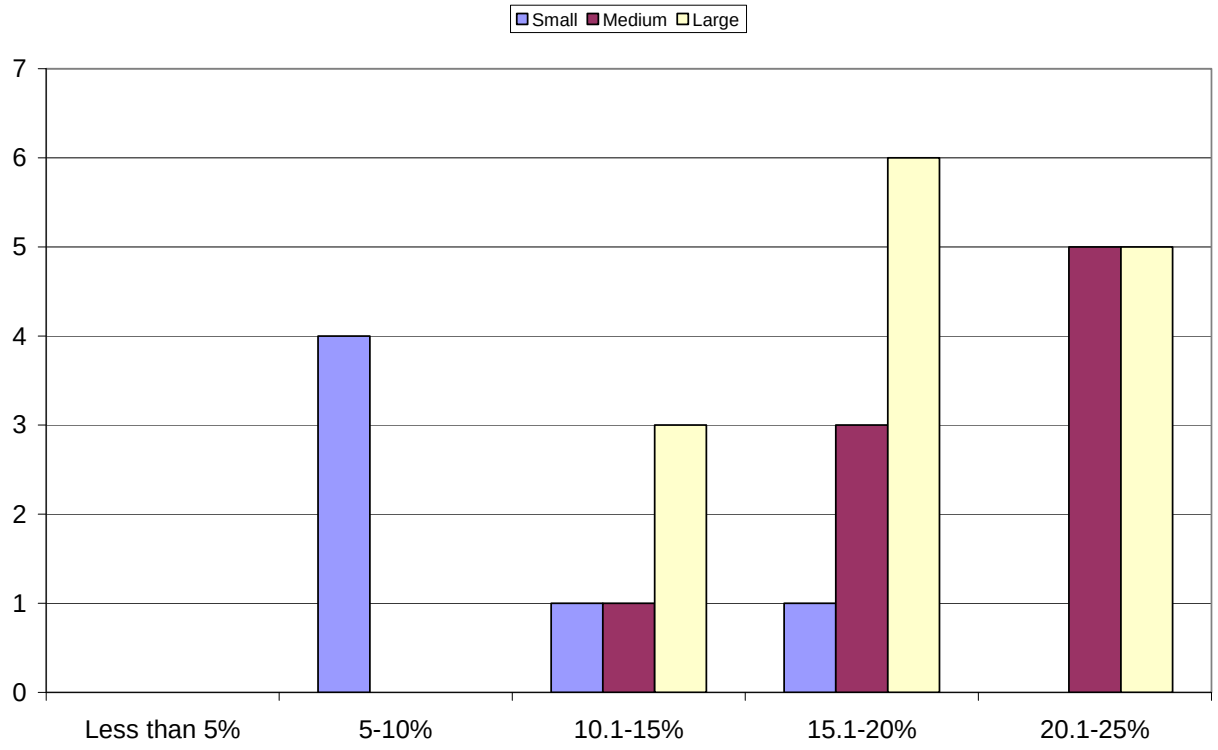


Q105. What is the *Saturday* layover as a percentage of platform time at your agency?



Copyright National Academy of Sciences. All rights reserved.

Q105. What is the *Sunday* layover as a percentage of platform time at your agency?



Agencies deal with the layover requirement by adding additional time into the schedules in general. Several respondents noted that this results in less efficient schedules. If minimum requirements were not in place, over half of the agencies sampled would continue using their current practice for scheduling layover time. This suggests a generally conservative approach to scheduling. Some would only add sufficient time to ensure that the next run would start on time, while others would shift layover time around in order to maximize schedule efficiency.

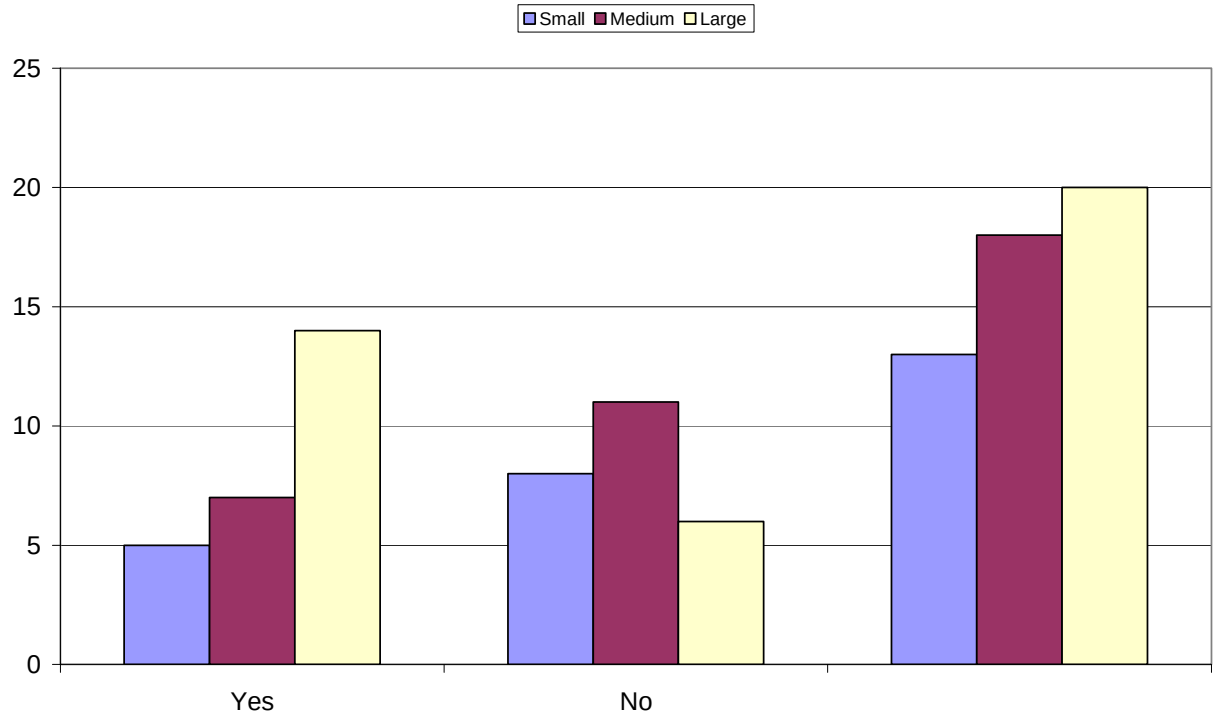
88. How would your agency address minimum layovers if no labor agreement restrictions were in place?

	Small	Medium	Large	Total	%
Add sufficient time to allow next run to start on-time	1	2	1	4	11%
Agreement between operations and management	1			1	3%
Industry standards		1		1	3%
Percentage of running time		1	1	2	5%
Same as current	4	6	9	19	51%
Schedule less time			1	1	3%
Scheduler discretion		1		1	3%
Shift layovers around to maximize schedule efficiency		2	2	4	11%
Use 10% minimum rule		1	1	2	5%
Would not address	1	1		2	5%
				37	

Copyright National Academy of Sciences. All rights reserved.

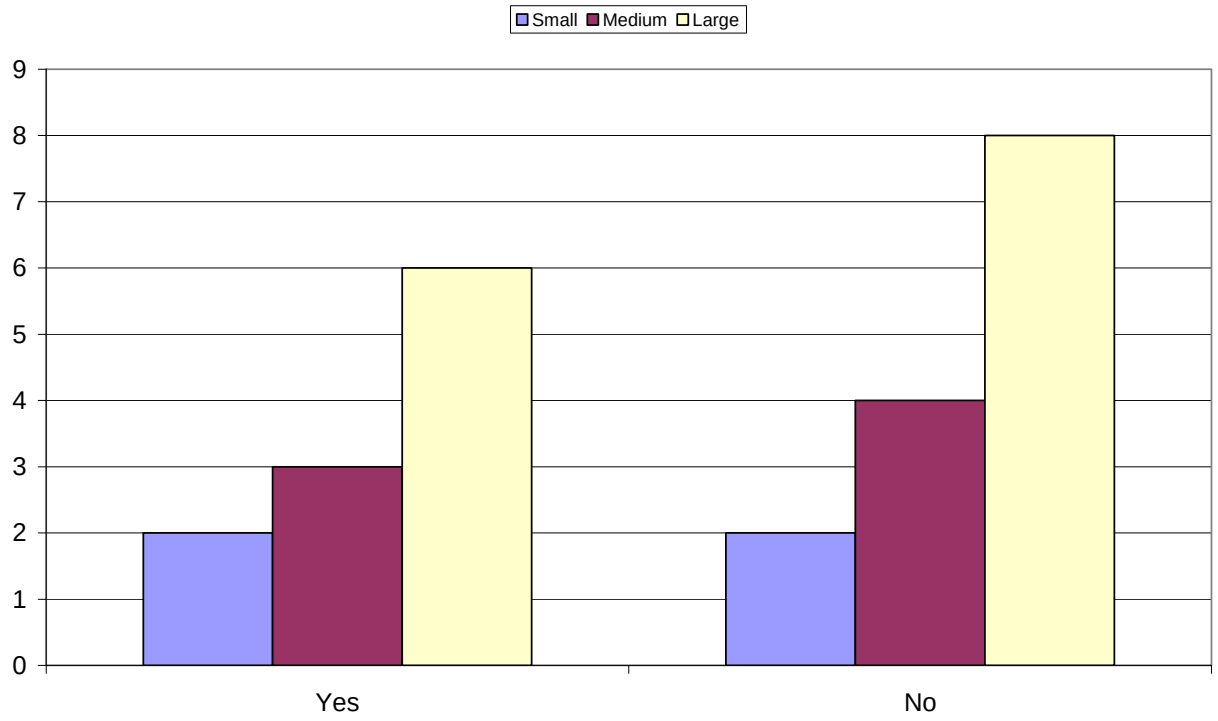
Approximately half of the participating agencies provide mid-route layover time. The practice was more prevalent in large agencies (70 percent), and is often related to timed transfers at mid-route points. Among agencies that provide mid-route layover time, only 44 percent count that time toward the minimum layover time.

Q89. Does your agency provide mid-route layover time on any of your routes (e.g. to ensure timed transfer at certain locations)?



Copyright National Academy of Sciences. All rights reserved.

Q90. If your agency provides mid-route layover time on any of your routes does this count toward minimum layover time for the route?



Agencies use a variety of methods to evaluate running and layover times. APC and AVL data are used by 29 percent of responding agencies. Small agencies were more likely to continue to rely on manual methods of data collection. Anecdotal input from operators and customers is also used. Whatever the data source, agencies periodically review running times and layover times on their routes while responding as needed to problems that arise.

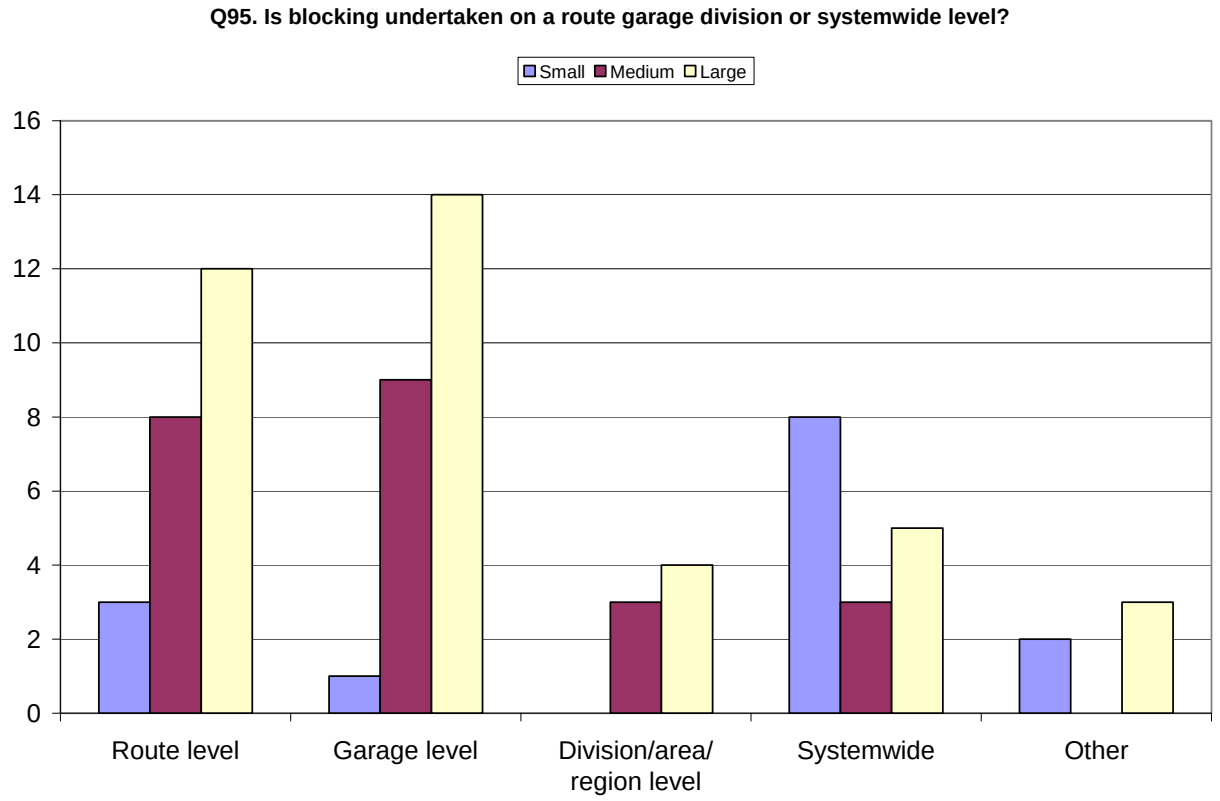
Q94. In summary, how does your agency manage running time/layover evaluation?

	Small	Medium	Large	Total	
Use APC/AVL data		7	5	12	29%
Professional judgment			1	1	2%
Analyze recovery ratios			2	2	5%
Operator input	4	1	4	9	21%
Union input			2	2	5%
Review with management/union	1	1	2	4	10%
Managed based on budget restraint			1	1	2%
Review on-time performance	2	3	3	8	19%
Ridechecks/Point checks	5		2	7	17%
Add layover time where possible	2	1		3	7%
Interline to equalize layover		1	1	2	5%
Customer complaints	2			2	5%
				42	

Copyright National Academy of Sciences. All rights reserved.

B.5 Blocking

Blocking practices are largely dependent on the agency size. Small agencies however are much more likely to undertake blocking on a systemwide basis, since services are usually based out of one location. Medium and large agencies generally block at the garage or the route level. In the "other" category, some agencies note that they block at the route level first, then review the blocks at the garage level for efficiencies, and others allow interlining of routes assigned to different garages. Surprisingly, given the wide application of computerized scheduling systems, only 46 percent of agencies keep historical comparisons of blocking solutions.



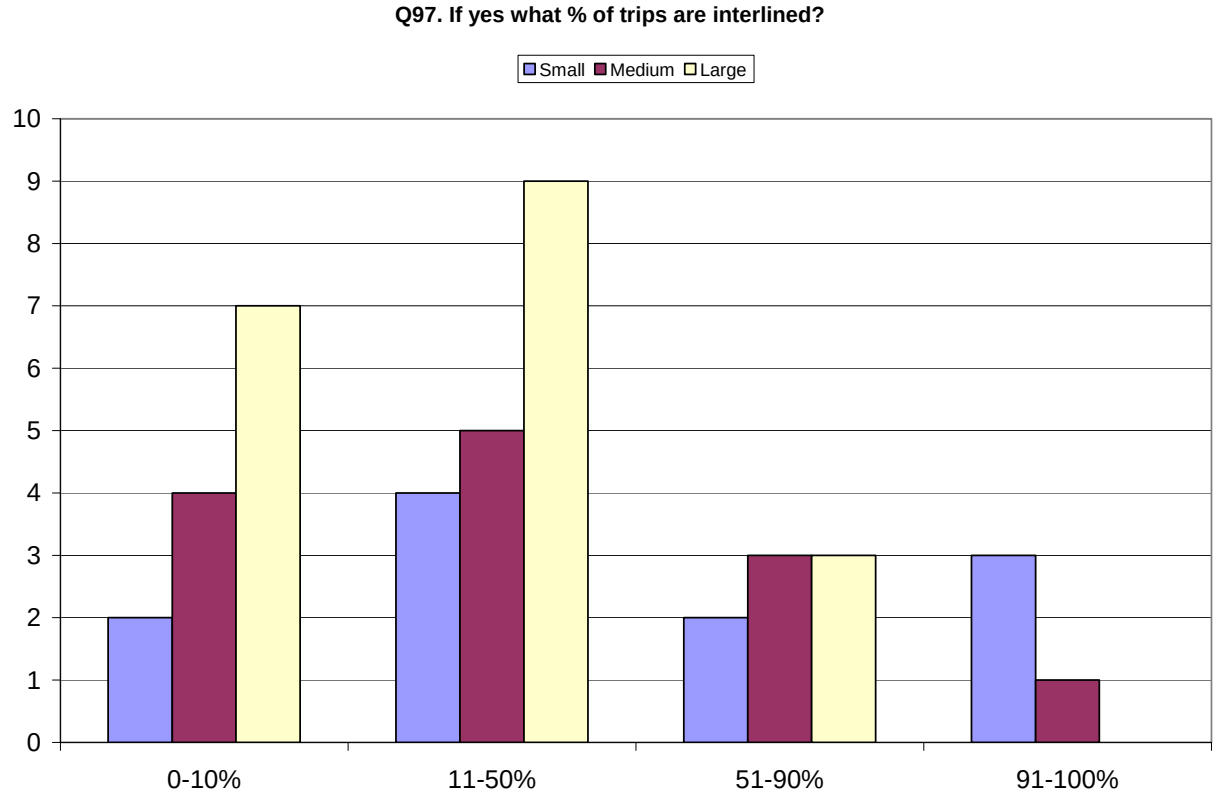
Copyright National Academy of Sciences. All rights reserved.

Only one-quarter of responding agencies indicated that they undertake "optimized" systemwide blocking, but the agencies that do this tend to do it with every bid or schedule change. A typical optimization would involve reblocking trips to minimize peak vehicle requirements and deadhead, interlining, and redistributing vehicles by garage, all concurrently. Among multi-garage agencies, 72 percent have conducted a garage optimization study within the past two years.

108. For multi-garage agencies, when was the last time you undertook a garage optimization study?

	Small	Medium	Large	Total	%
Never	1		2	3	12%
In progress		3	1	4	16%
Less than 1 year			3	3	12%
1 - 2 years		2	6	8	32%
2 - 5 years		1		1	4%
5+ years		1	1	2	8%
Each pick	1		2	3	12%
Upon opening a new garage			1	1	4%
				25	

Nearly all agencies (92 percent) reported interlining trips and blocks. Of these agencies, 30 percent interline10 percent or fewer of their trips, and 72 percent interline 50 percent or fewer of their trips. Small agencies reported a higher percentage of interlined trips.



Copyright National Academy of Sciences. All rights reserved.

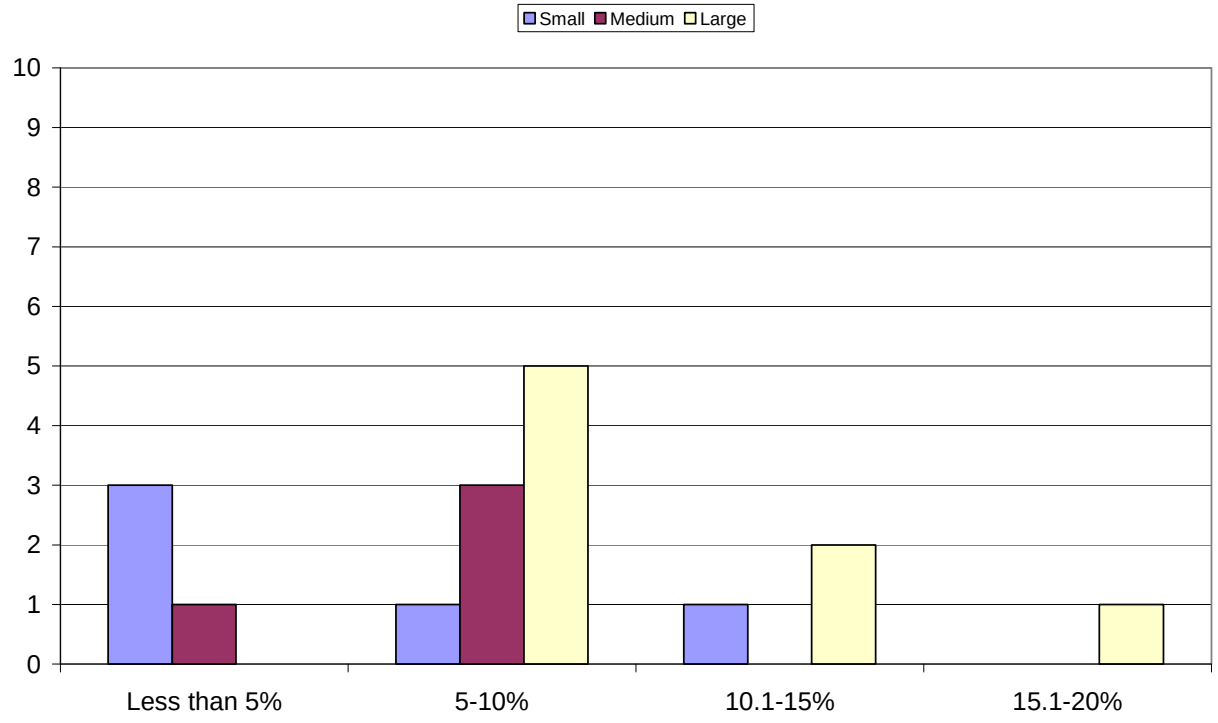
Among agencies that interline, 42 percent stated that there is evidence of negative reliability impacts from interlining. Large agencies were more likely to indicate negative reliability impacts (55 percent), compared to 38 percent of medium agencies and 25 percent of small agencies. The major issue is the spillover effect of delays on one route causing delays on the interlined route.

98a. Is there any evidence of negative reliability impacts of interlining at your agency? Please describe.

	Small	Medium	Large	Total	%
Deadhead between trips leads to late starts			4	4	20%
Delays on one route lead to delays on the interlined route	2	3	6	11	55%
Service control more difficult			1	1	5%
Staff complaints	1	1		2	10%
Hard to schedule breaks		1		1	5%
Customer confusion	1			1	5%
	4	5	11	20	

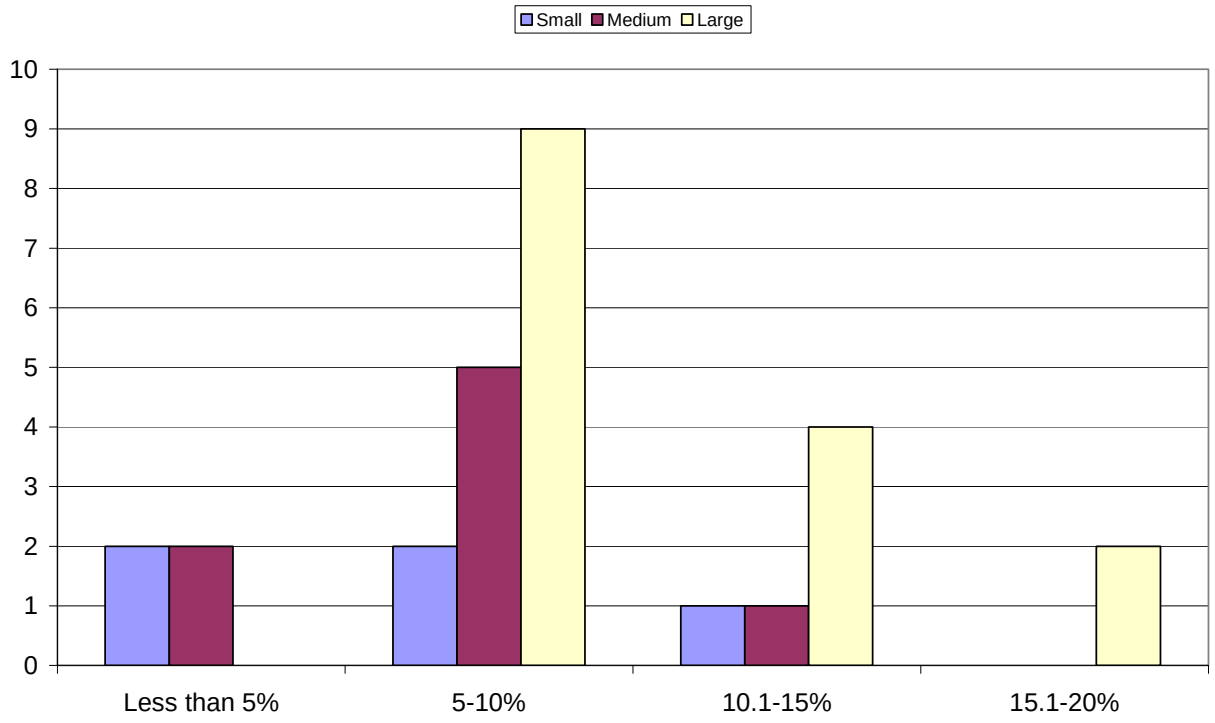
While deadheading between trips was indicated as an issue in interlining, total deadhead time (including pull-out and pull-in time) usually accounts for less than ten percent of platform time among responding agencies. Deadhead time is less of a factor on weekends.

Q 107. Overall - What are deadhead plus garage pull-in and pull-out times as a percentage of platform at your agency?

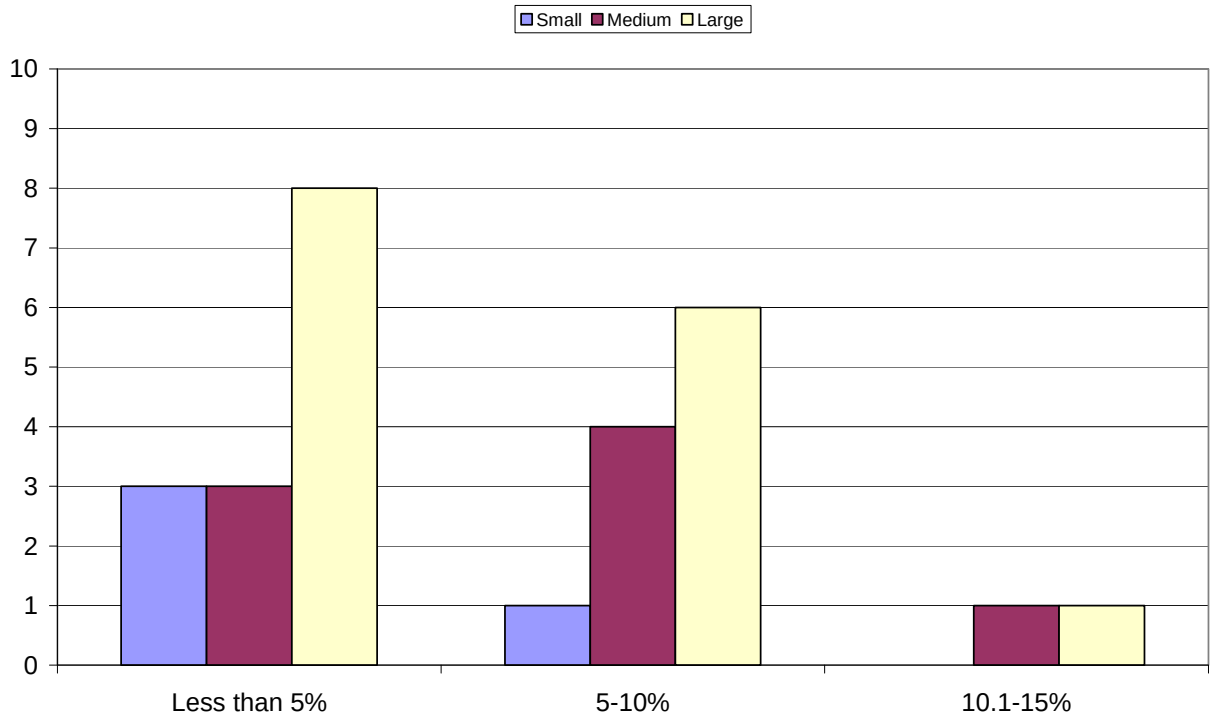


Copyright National Academy of Sciences. All rights reserved.

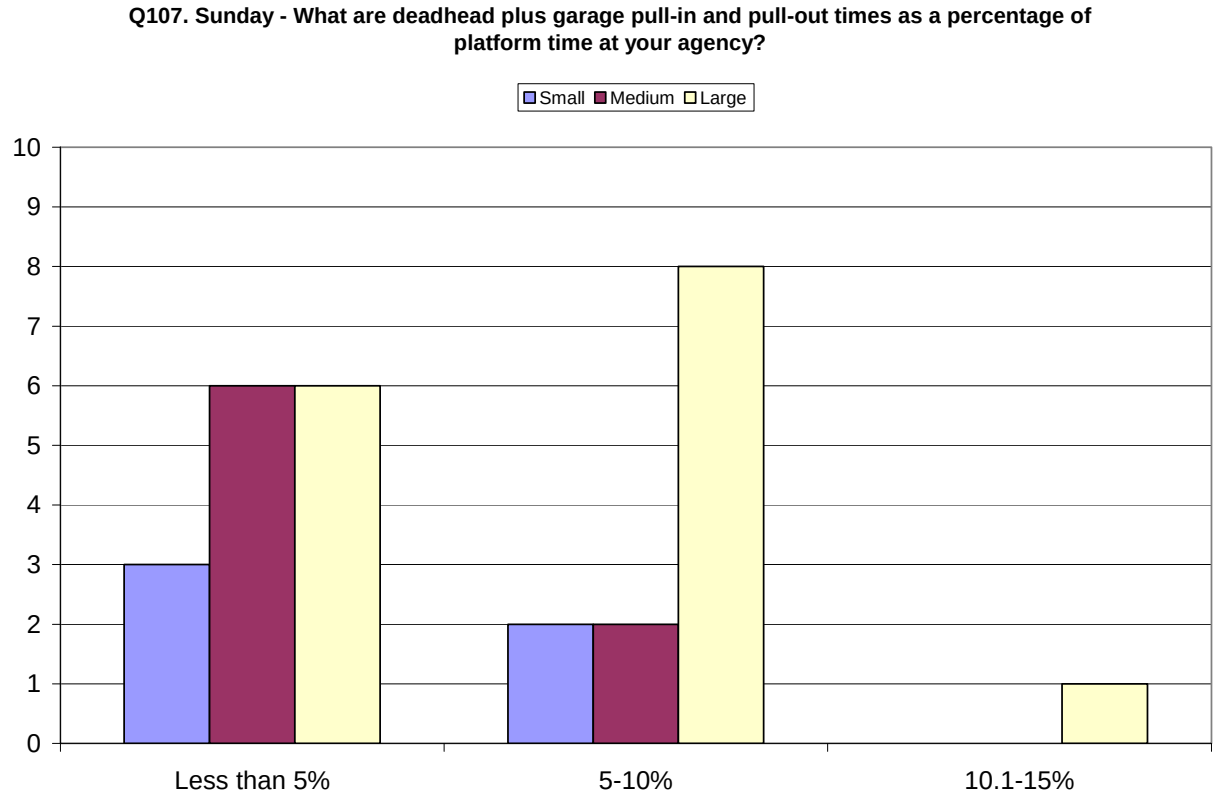
Q107. Weekday - What are deadhead plus garage pull-in and pull-out times as a percentage of platform time at your agency?



Q107. Saturday - What are deadhead plus garage pull-in and pull-out times as a percentage of platform time at your agency?



Copyright National Academy of Sciences. All rights reserved.

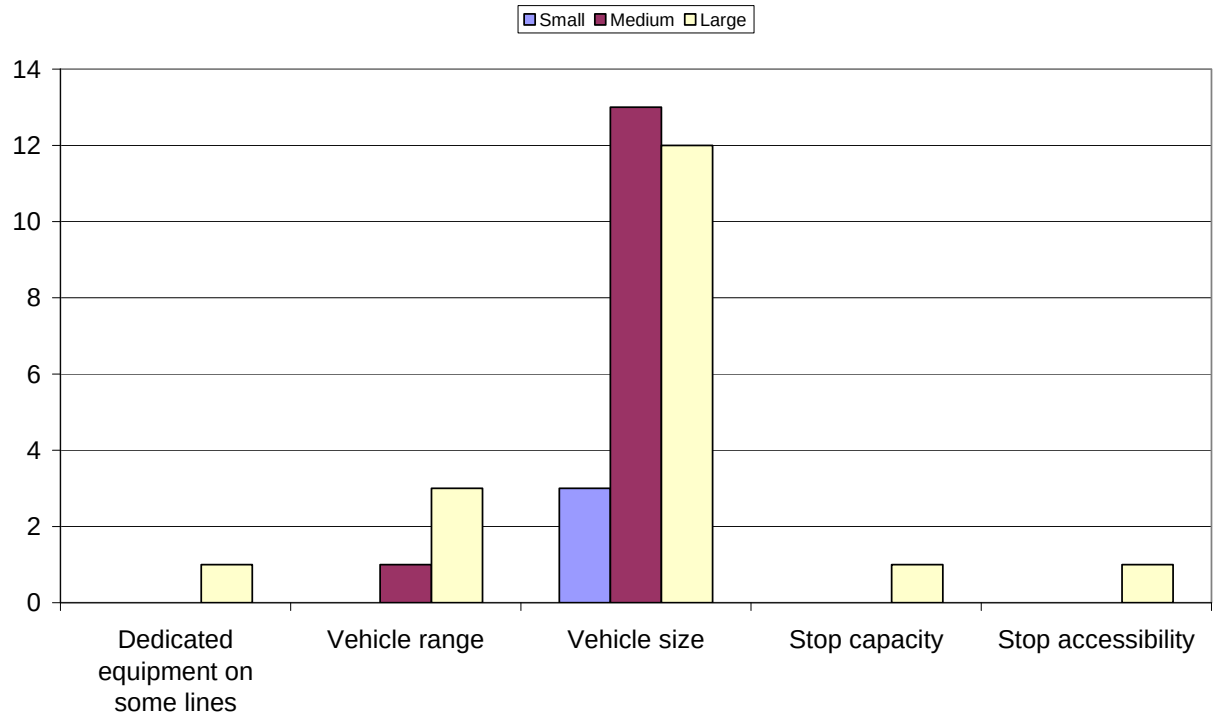


Consideration of related scheduling tasks is very common in blocking. Eighty percent of respondents indicate that the impacts on runs (through block lengths, for example) are considered when creating blocks.

Copyright National Academy of Sciences. All rights reserved.

Survey responses regarding constraints and other influencing factors on various aspects of scheduling are especially important. Over 70% of agencies face vehicle type constraints, with vehicle size the most frequently mentioned constraint.

Q111. If you have vehicle type and/or modal constraints to consider when blocking, please describe.



Most agencies reported no labor contract limitations on the blocking process (71 percent overall, with no differences by agency size). The most often noted labor contract constraints included break requirements, minimum layover/recovery time, split run limitations, spread limitations, and rules related to street reliefs.

102. If there are any labor contract limitations/constraints on the blocking process, please describe.

	Small	Medium	Large	Total	%
Required breaks	2	1	2	5	36%
Minimum layover/recovery requirements			3	3	21%
Owl routes cannot be split			1	1	7%
Straight run percentage			2	2	14%
Street relief constraints		1	1	2	14%
Interlining percentage		1		1	7%
Start time constraint		1		1	7%
Hour guarantee	1			1	7%
Spread limitation	2			2	14%
	3	4	7	14	

Copyright National Academy of Sciences. All rights reserved.

In deciding if a blocking solution is efficient, number of peak vehicles required and percentage of layover and recovery time are the parameters used most frequently. Small agencies are more likely to focus on layover and recovery time. Only one agency considered total hours to define blocking solution efficiency.

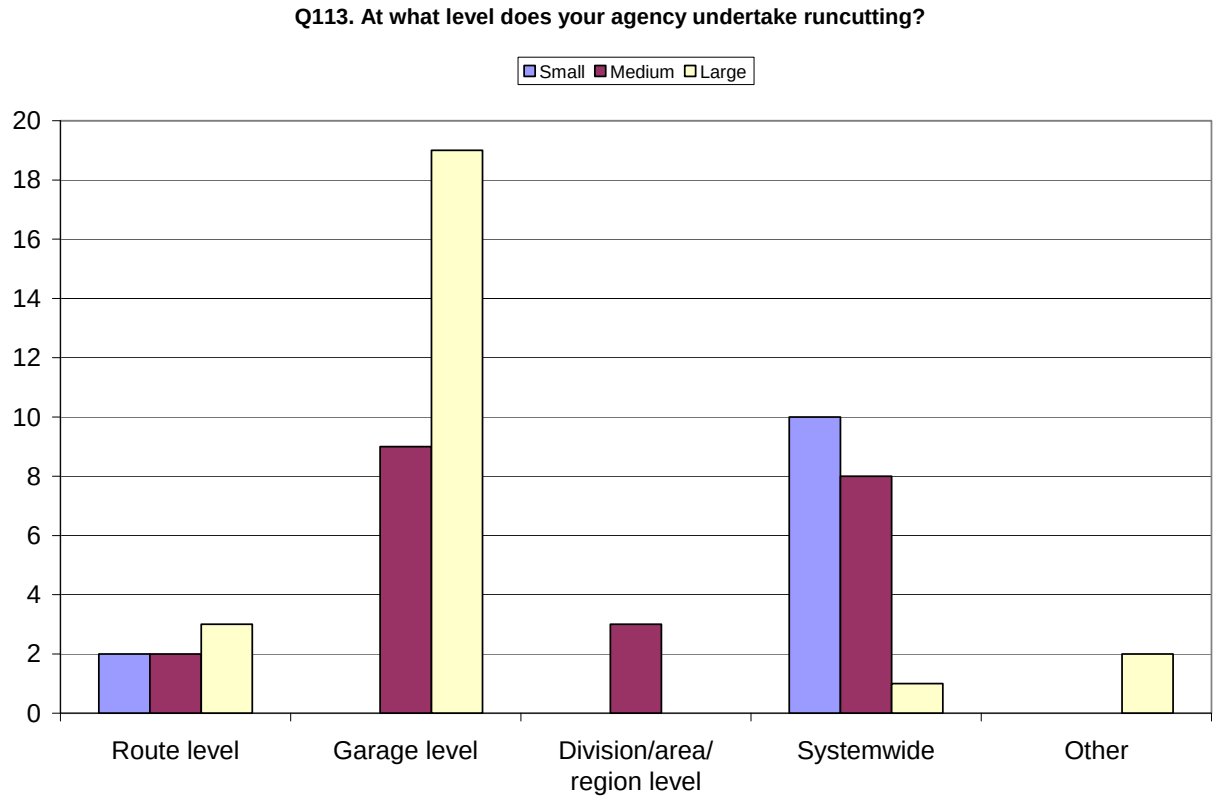
103. What parameters are used to define if a blocking solution is efficient (e.g., peak vehicles, % layover, etc.)? Please describe.

	Small	Medium	Large	Total	%
Peak vehicles	2	7	15	24	67%
% Layover/recovery	5	4	6	15	42%
Headways		1	1	2	6%
Minimize vehicle hours			2	2	6%
Revenue/platform ratio			1	1	3%
Block length		2	1	3	8%
Total hours			1	1	3%
Operator requirement		1		1	3%
Desirability of work for drivers	1			1	3%
	7	12	17	36	

Copyright National Academy of Sciences. All rights reserved.

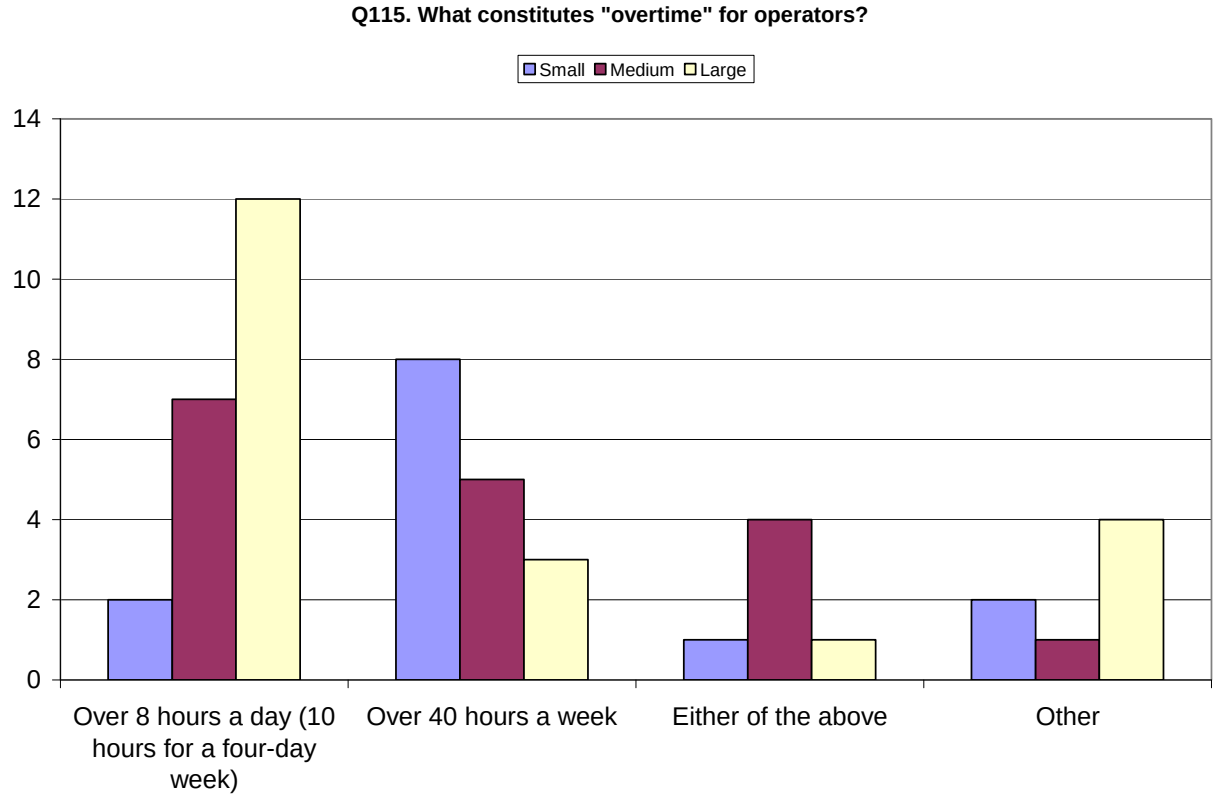
B.6 Runcutting

Runcutting is most often undertaken at the garage level basis. Small agencies are much more likely to runcut systemwide, since all operations are typically based out of a single facility. Over three-quarters of responding agencies reported that they keep historical comparisons of runcut solutions (compared with a much lower 46 percent that keep blocking solutions).



Copyright National Academy of Sciences. All rights reserved.

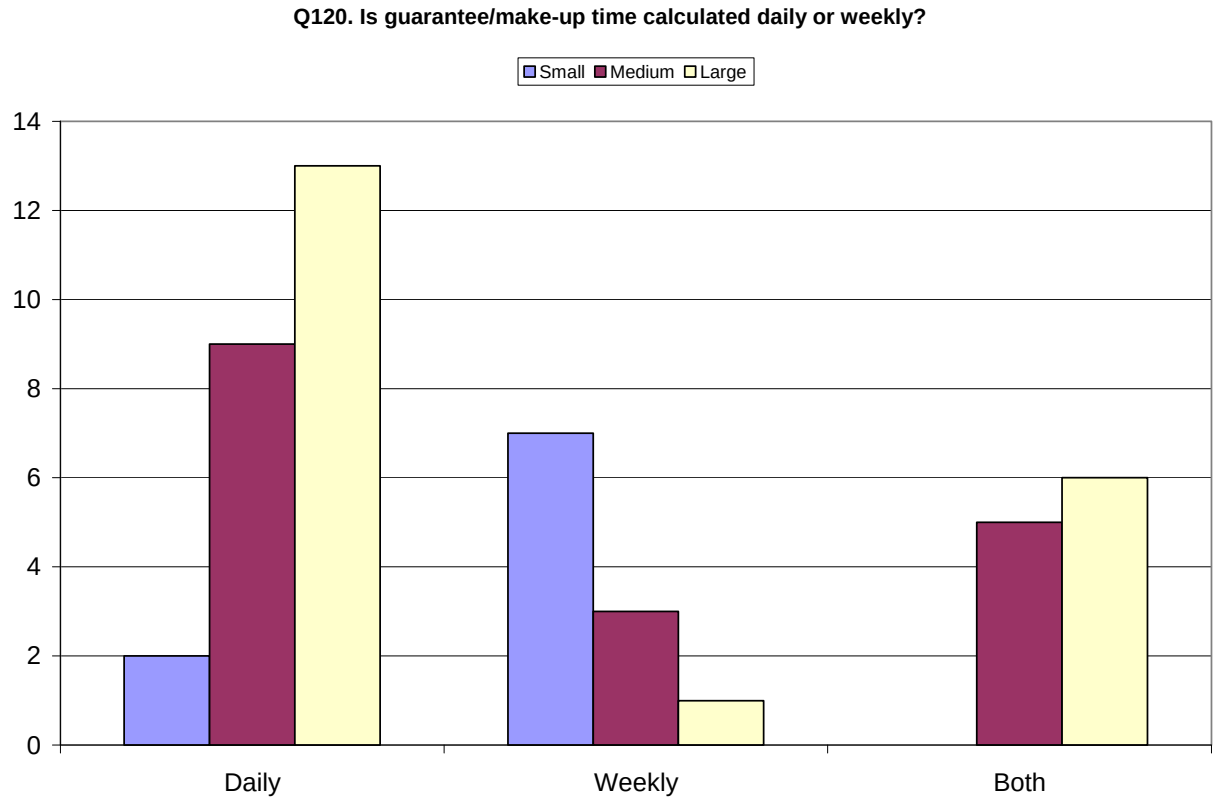
Many agencies must pay overtime for work over eight hours a day (42 percent), while 32 percent pay overtime for more than 40 hours a week and 12 percent pay under either circumstance. Small agencies were much more likely to pay overtime on a weekly basis.



A key issue for many transit agencies is the trade off between building longer shifts (with more overtime) and hiring additional staff. By a wide margin, agencies prefer to overtime to hiring new operators. Over 90 percent of responding agencies subscribed to this view, noting that overtime is more economical, that there are benefits to minimizing the work force, and that it is difficult to find qualified operators. Very few agencies have undertaken a detailed analysis of the issue, but those that have indicated that overtime was a more efficient solution than hiring new operators. The scheduling manual should include a detailed discussion of this issue, focusing on the main parameters and key decision drivers without being overly prescriptive and considering issues such as the impacts of weekly vs. daily overtime, the distribution of overtime among different run types, and the location of the scheduling department in the organizational structure.

Copyright National Academy of Sciences. All rights reserved.

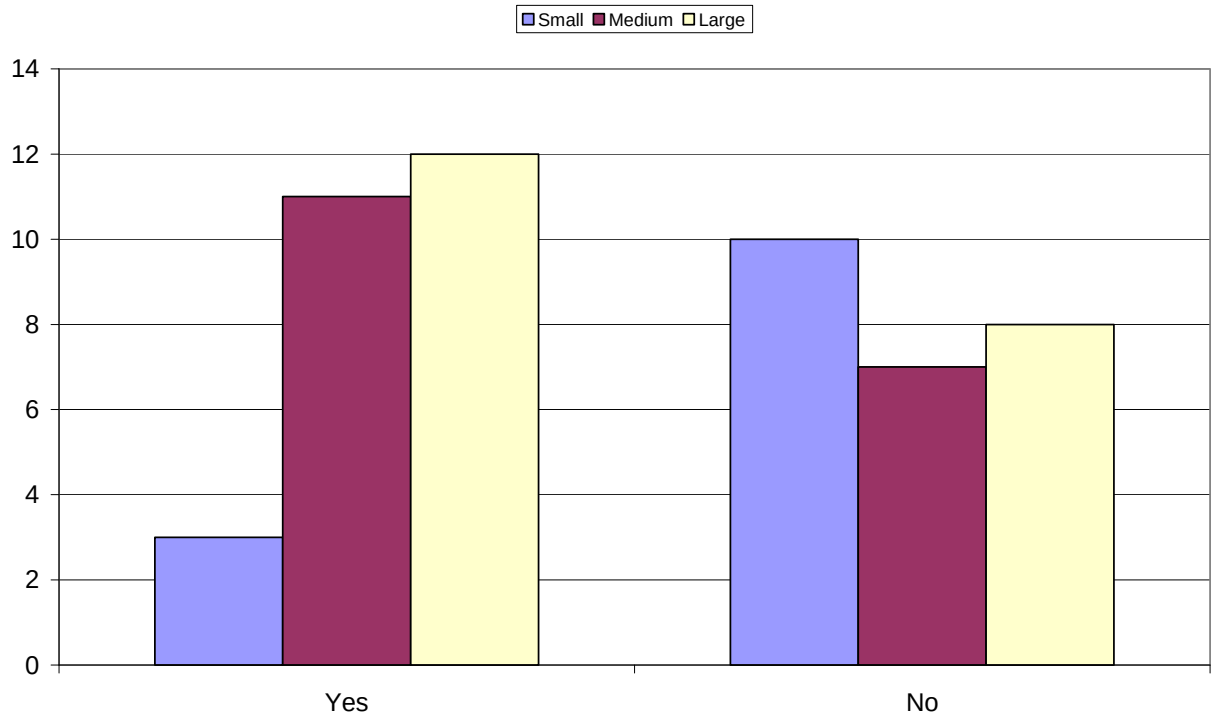
Nearly all agencies have guaranteed minimum time for full-time operators. Roughly half of the agencies calculate guaranteed time daily, but one-quarter calculate it weekly and one-quarter have both daily and weekly guarantees. As with overtime, small agencies are more likely to guarantee weekly time.



Copyright National Academy of Sciences. All rights reserved.

Half of responding agencies require daily make-up time. A majority of medium and large agencies require daily make-up time, but most small agencies do not (in line with overtime policies). Almost 70 percent of agencies do not require weekly make-up time (daily make-up time eliminates the need for weekly make-up).

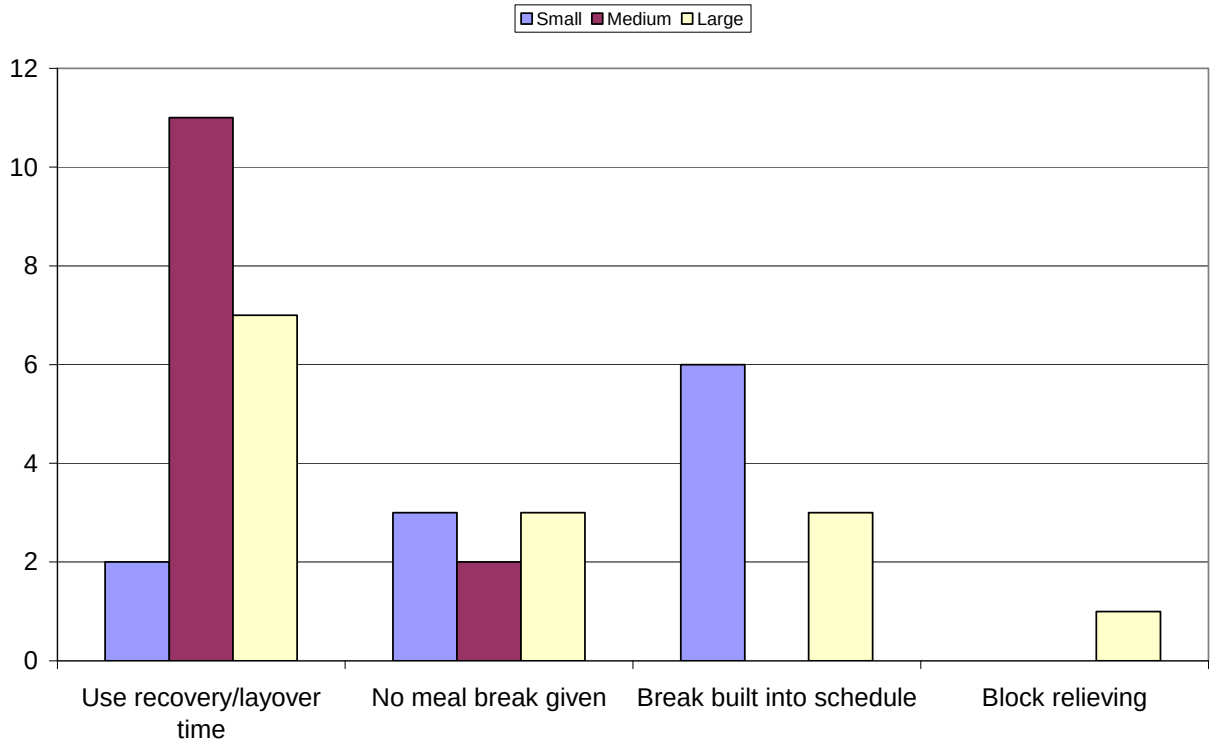
Q121. Does your agency require "make-up" time to fill a run that would otherwise be less than 8 (5-day week) or 10 (4-day week) hours per day?



Copyright National Academy of Sciences. All rights reserved.

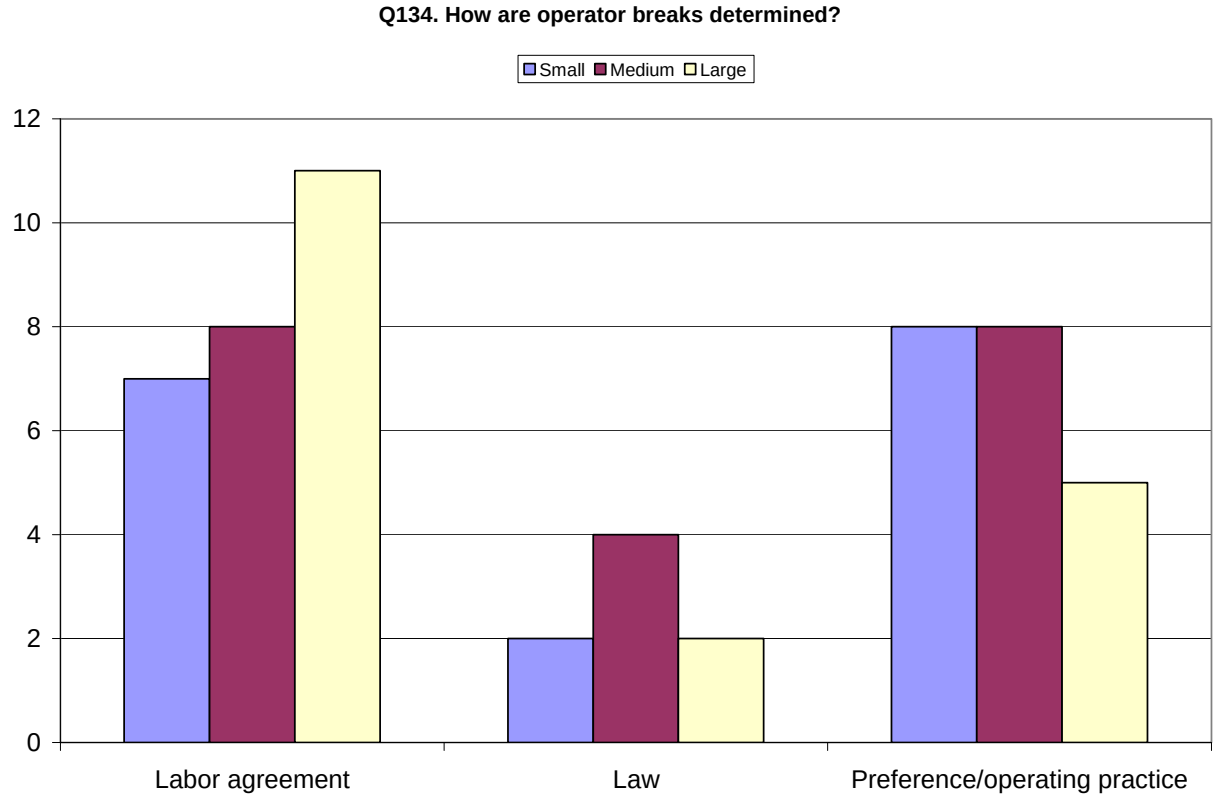
Operator breaks, for meals or other purposes, are a challenge for schedulers. Agencies in California are forced to address this issue in response to a recent change in State law. Agencies typically build breaks into the schedule using recovery and layover time, which is potentially an inefficient practice. Not all agencies give meal breaks.

Q133. Describe how your agency schedules operator meal breaks and operator rest breaks.



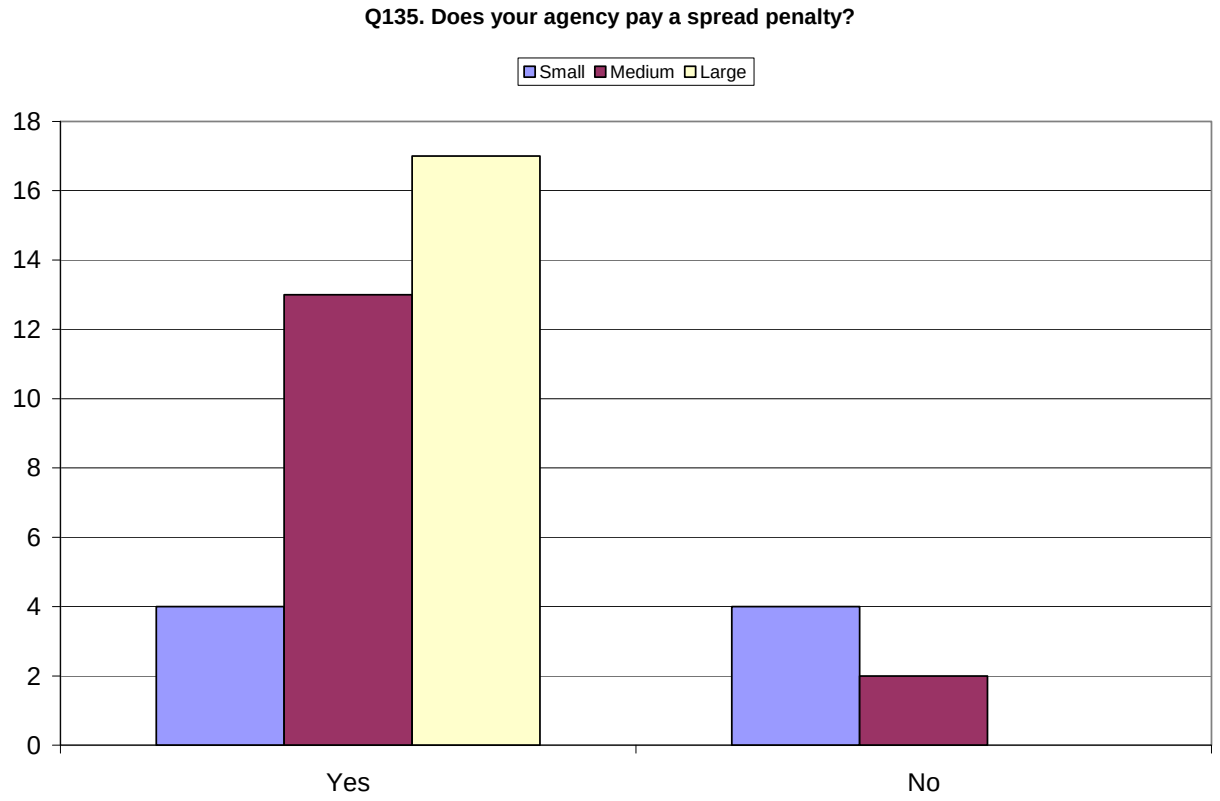
Copyright National Academy of Sciences. All rights reserved.

Operator breaks are mandated by either labor agreement or law in most large agencies, but overall many agencies schedule breaks by operating practice/preference.



Copyright National Academy of Sciences. All rights reserved.

The majority of agencies (85 percent) pay a spread penalty for certain split shifts, although only half of small agencies pay a spread penalty. Spread time is the elapsed time between the beginning of the first piece and the end of the last piece of a multi-piece run. Typically, spread time beyond a given level (ranging from 9 to 12 hours in this survey, with most at 11 to 12 hours) is paid at time-and-a-half. A few large agencies have a second level beyond which operators are paid at double time. Spread maximums range from 11 hours to 14 hours. Report and turn-in time are included in the spread calculation in over 75 percent of agencies.



A slight majority of agencies (53 percent) reported limitations on multi-piece runs. Large agencies were more likely to have restrictions. The most common limitation specified by agencies was a maximum of two pieces, followed by a three piece maximum, and a requirement that one break must be paid in a three-piece run.

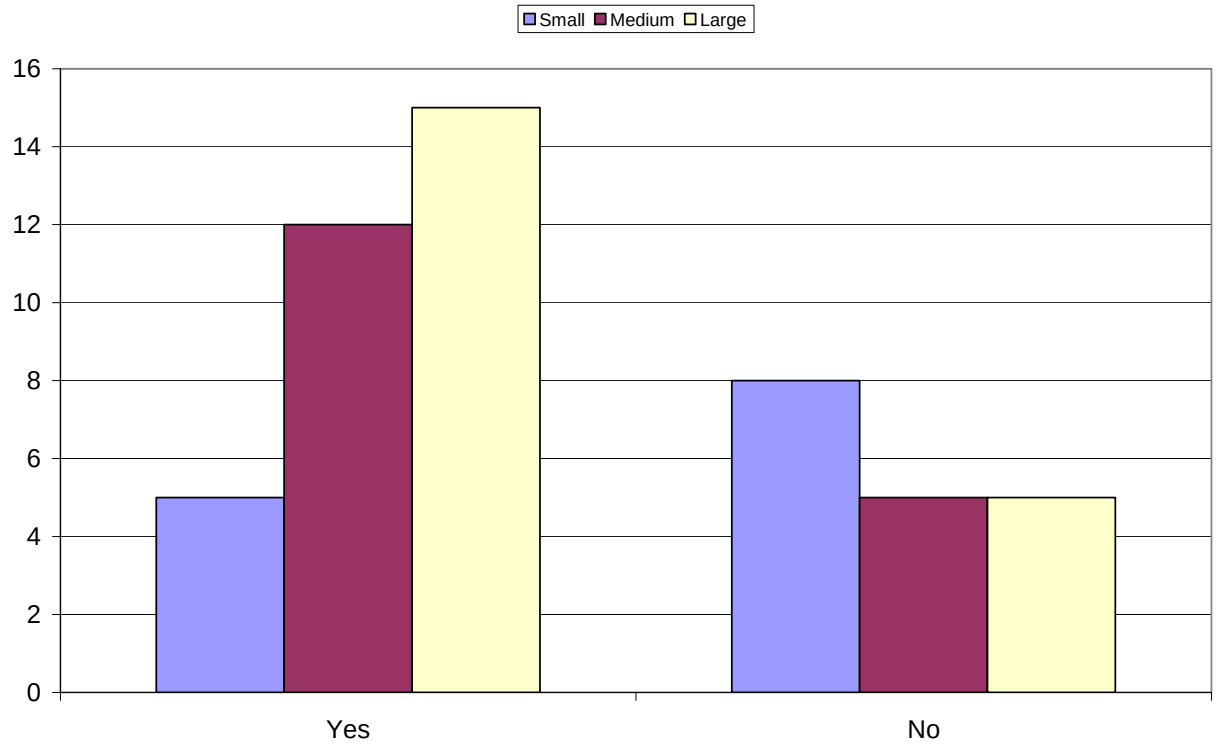
138. If there are limitations on multi-piece runs, please describe.					
	Small	Medium	Large	Total	%
2 piece maximum	4	2	6	12	46%
3 piece maximum		3	2	5	19%
One break must be paid	1	1	2	4	15%
Saturdays only			1	1	4%
Total split percentage maximum			3	3	12%
Shift duration minimum	1		1	2	8%
1 hour minimum between splits		1		1	4%
				26	

Copyright National Academy of Sciences. All rights reserved.

Almost all agencies (92 percent) pay travel time or relief allowances. Agencies reported a variety of means by which operators travel to and from relief points. Among large agencies, bus or rail is the most common option, while medium and small agencies are more likely to rely on an agency vehicle.

Nearly two-thirds of agencies have a contract limitation on the number of part-time operators. Such limitations are more prevalent at large and medium-sized agencies. Limitations may be expressed as actual positions or as a percentage of total operators. Allowable percentages range from seven percent to 33 percent.

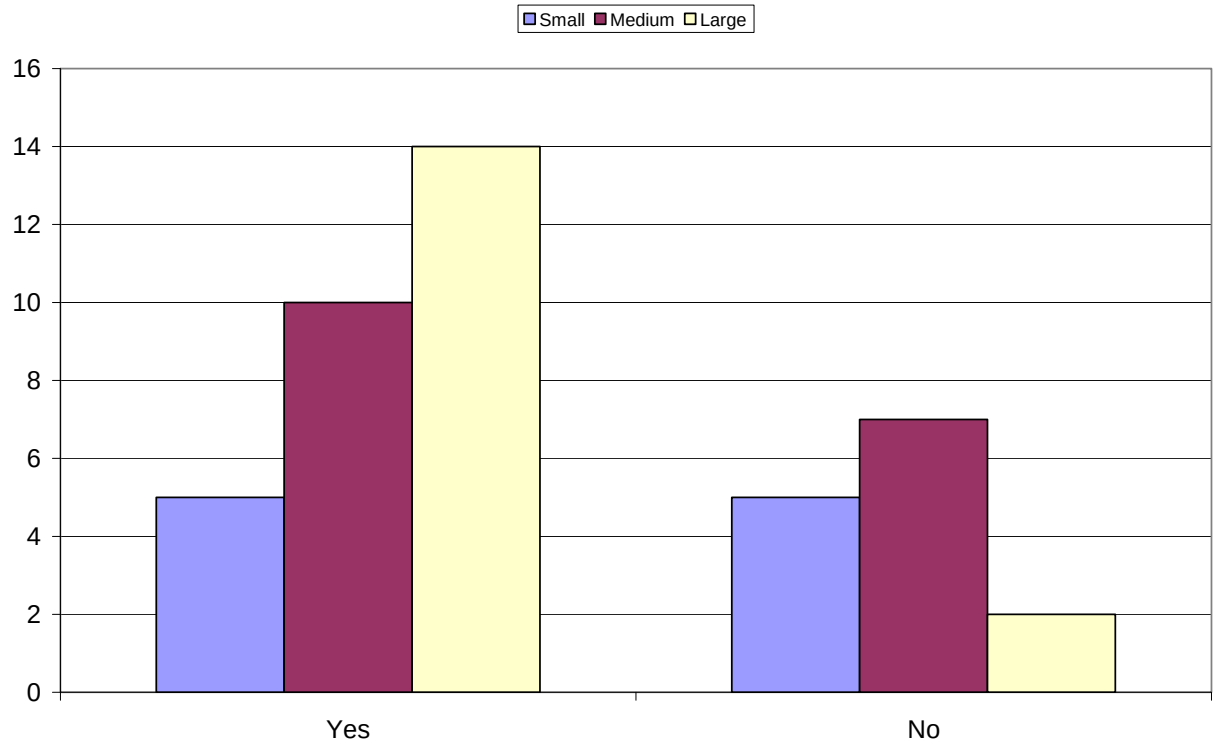
Q124. Are there contract limitations on the number or percentage of part-time operators?



Copyright National Academy of Sciences. All rights reserved.

Over two-thirds of responding agencies report upper and lower limits for hours worked per week for PTOs. A typical upper limit is 30 hours per week, and a typical lower limit (which is much less common) is 15 to 20 hours per week.

Q126. Are there upper and lower limits for weekly hours worked for part-time operators?



Additional limitations on the use of PTOs were reported by 38 percent of responding agencies. These limitations include times of day or days of week that they can work, specific restrictions on types of runs or routes, and lower priority than full-time operators.

Only one-quarter of respondents reported guaranteed minimum hours for part-time runs. This was more common at large agencies. Most minimum guarantees were in the two to three hour range.

Copyright National Academy of Sciences. All rights reserved.

As with other aspects of scheduling, runcutting constraints reported in the survey are of particular interest. Key limitations in the labor agreement included split run limits (57 percent), spread limits (32 percent), daily hour guarantees (27 percent), and overtime pay requirements (22 percent). When asked which constraints impose the greatest restriction on runcut development, agencies were most likely to mention spread restrictions, breaks, and straight run percentages.

139. Please describe any constraints that pose the greatest restriction or impacts on runcut development.

	Small	Medium	Large	Total	%
Breaks	3	2	4	9	25%
Budget	1			1	3%
Deadhead pay	1			1	3%
Driver turnover			1	1	3%
Hours minimum for operators	1	1	1	3	8%
Labor agreement			1	1	3%
Line of origin restrictions		1		1	3%
Manual process is time consuming		1		1	3%
Overtime			2	2	6%
Part time operator restrictions		1	2	3	8%
Relief points		1	2	3	8%
Software limitations			1	1	3%
Spread penalty			2	2	6%
Spread restrictions	2	6	3	11	31%
Straight run percentages		3	3	6	17%
Travel time for relief			1	1	3%
Tripper limitations		1	1	2	6%
				36	

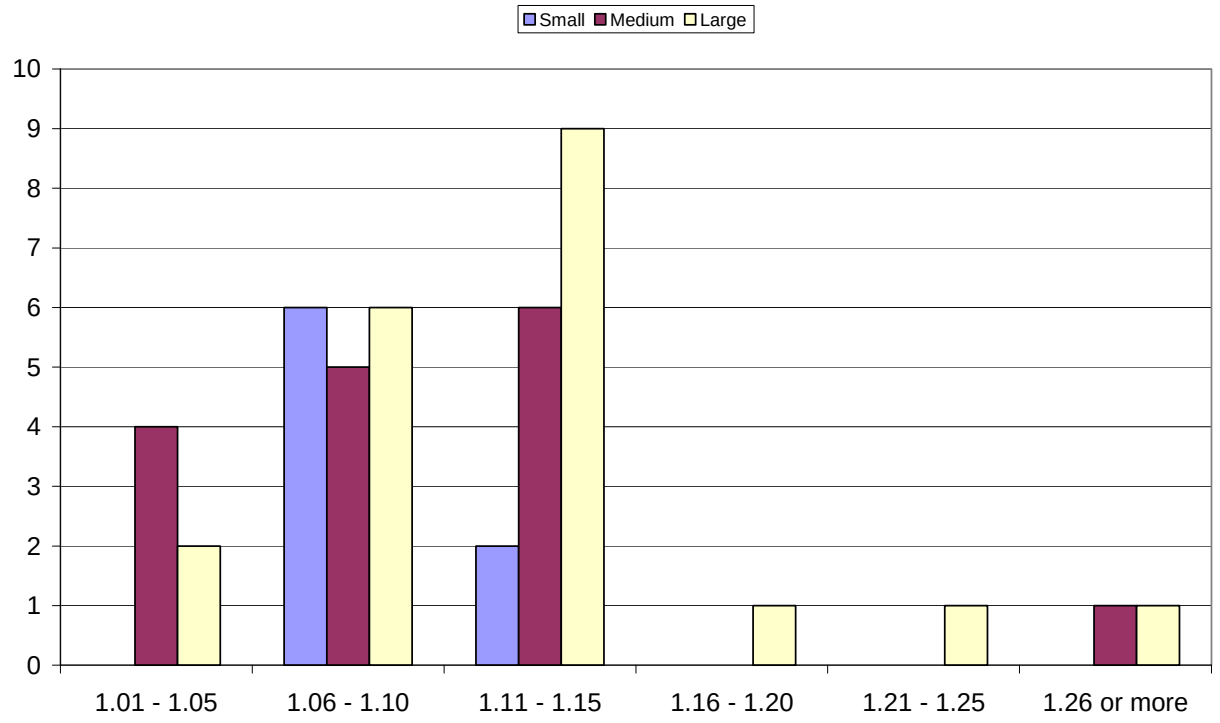
Copyright National Academy of Sciences. All rights reserved.

The most common parameters used to define if a runcut is efficient are pay to platform ratio and the number of operators required. Surprisingly, total pay hours is only used by a few respondents. Reported pay to platform ratios by day of week are shown below. Pay to platform ratio is of course heavily impacted by the labor agreement and therefore is not necessarily a good indicator of the efficiency of one agency to the next.

117. Parameters used to define if a runcut is efficient

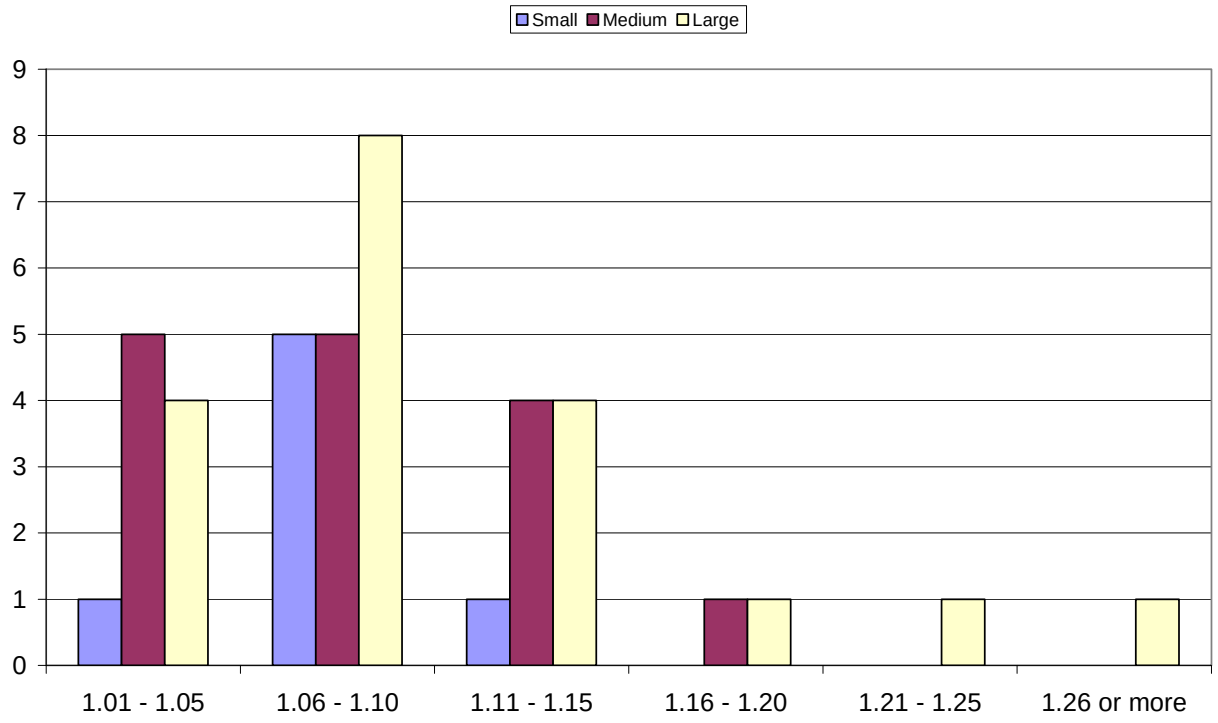
	Small	Medium	Large	Total	%
Cost		1	3	4	9%
Efficiency indicator on software package	1		1	2	4%
Number of operators	3	11	10	24	52%
Number of trippers		2	1	3	7%
Overtime	1	2	1	4	9%
Pay/platform ratio	2	12	17	31	67%
Peak vehicles			1	1	2%
Total miles			1	1	2%
Total pay hours	1		2	3	7%
Minimizing penalty time		1		1	2%
Spread time	2			2	4%
Compare to previous runcuts	2			2	4%
Number of split runs	2			2	4%
				46	

Q112. Weekday - Please estimate your agency's pay to platform ratio from the most recent runcut without including extraboard in the total pay hours.

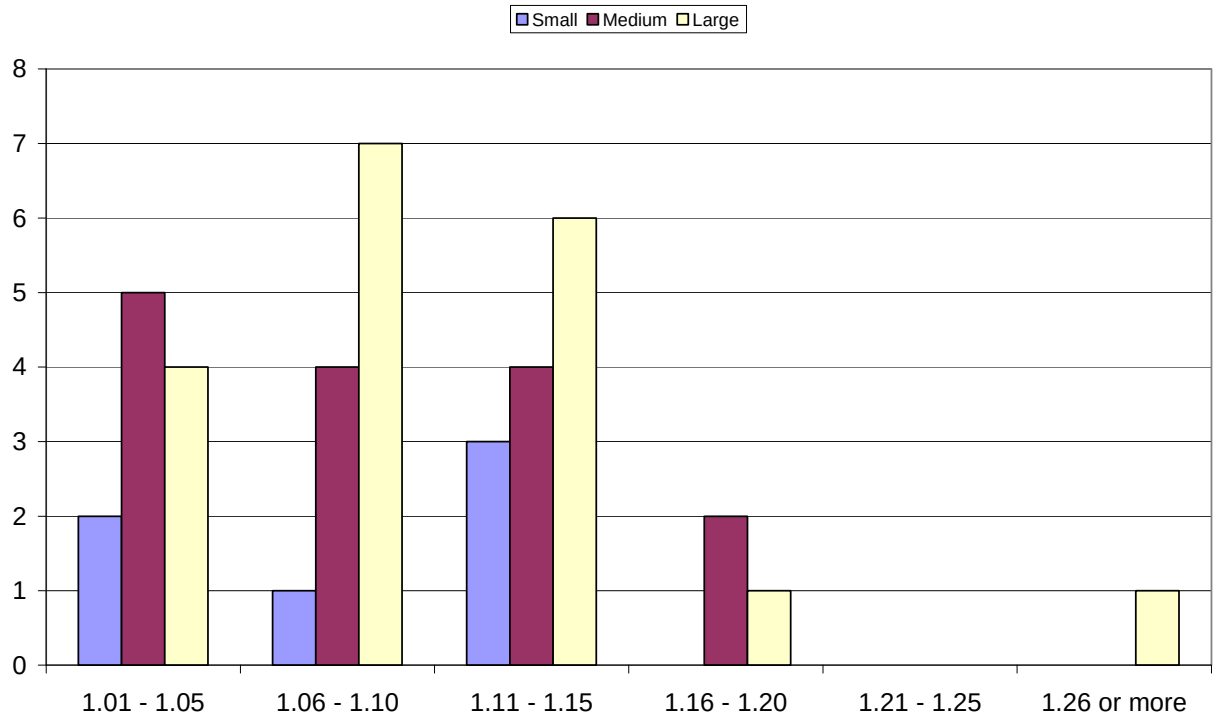


Copyright National Academy of Sciences. All rights reserved.

Q112. Saturday - Please estimate your agency's pay to platform ratio from the most recent runcut without including extraboard in the total pay hours.



Q112. Sunday - Please estimate your agency's pay to platform ratio from the most recent runcut without including extraboard in the total pay hours.



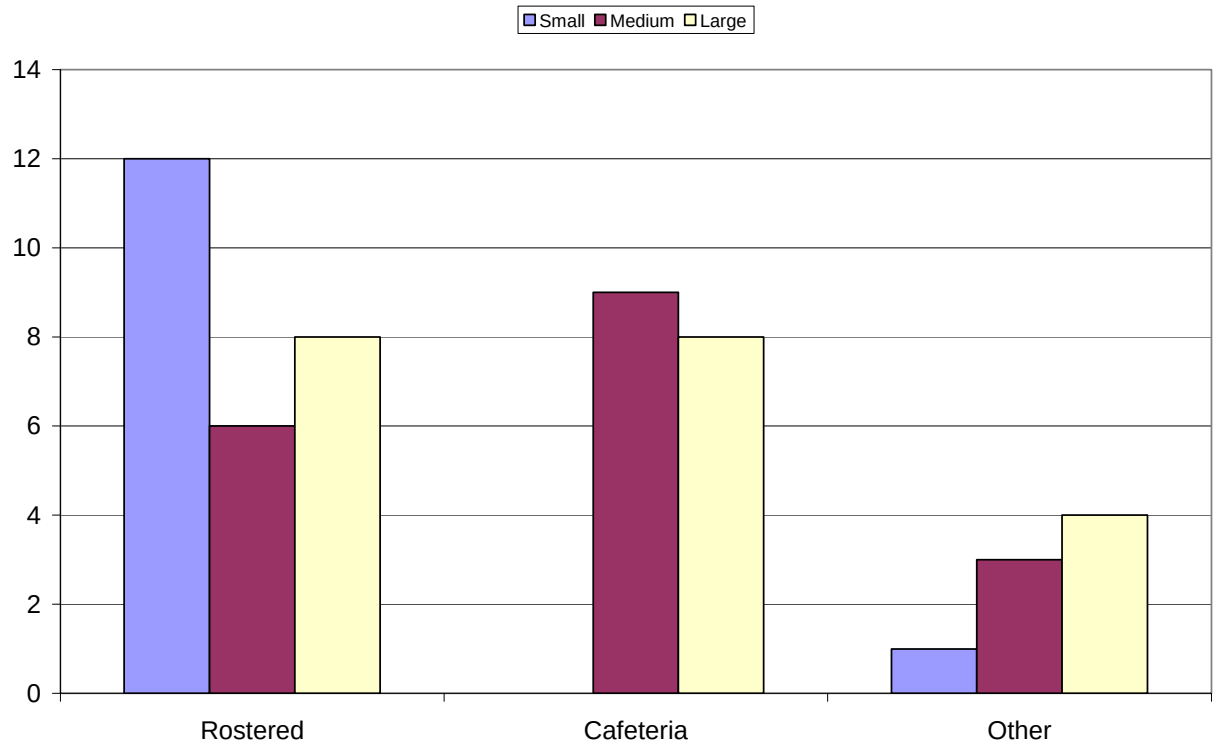
Copyright National Academy of Sciences. All rights reserved.

B.7 Period Rostering

Respondents were asked to provide a brief overview of how rosters are created and administered. A variety of approaches and rules were observed. Agencies roster by combining daily assignments into a five-day work week (or a 4/10 work week). Rostering is done at the garage or division level. Days off may be assigned or picked by the operators, and consecutive days off may be required. The weekly assignment may be required to consist of the same run each day, or runs and routes may be mixed. Operators bid by seniority.

Picks were rostered in half of the agencies surveyed, while one-third of respondents use a cafeteria-style system and the remaining agencies do some combination of both. The combinations differ by full-time/part-time, weekday/weekend, 4-10/others, and by division/mode. Small agencies rostered almost exclusively, medium-sized agencies used cafeteria style more often, and large agencies used both methods evenly.

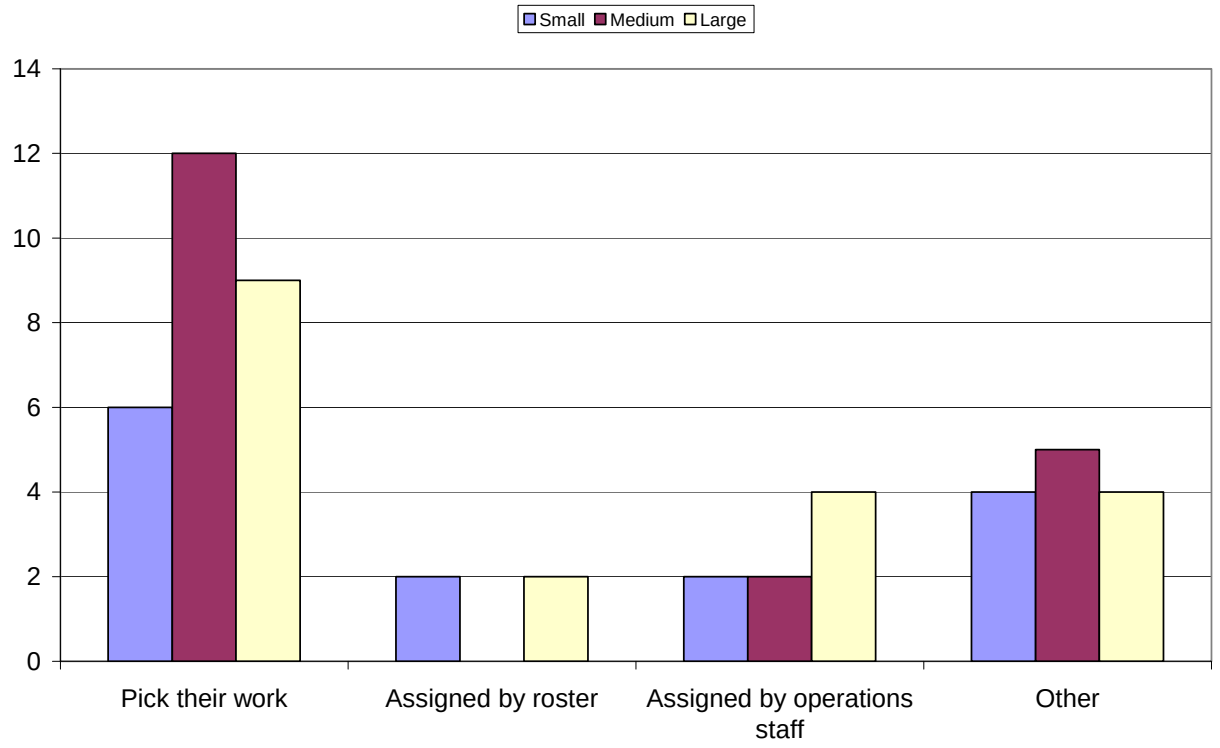
Q142. Are picks rostered or is a cafeteria style system used?



Copyright National Academy of Sciences. All rights reserved.

As noted above, part-time operators are sometimes treated differently in terms of rostering. At 60 percent of responding agencies, PTOs pick their own work.

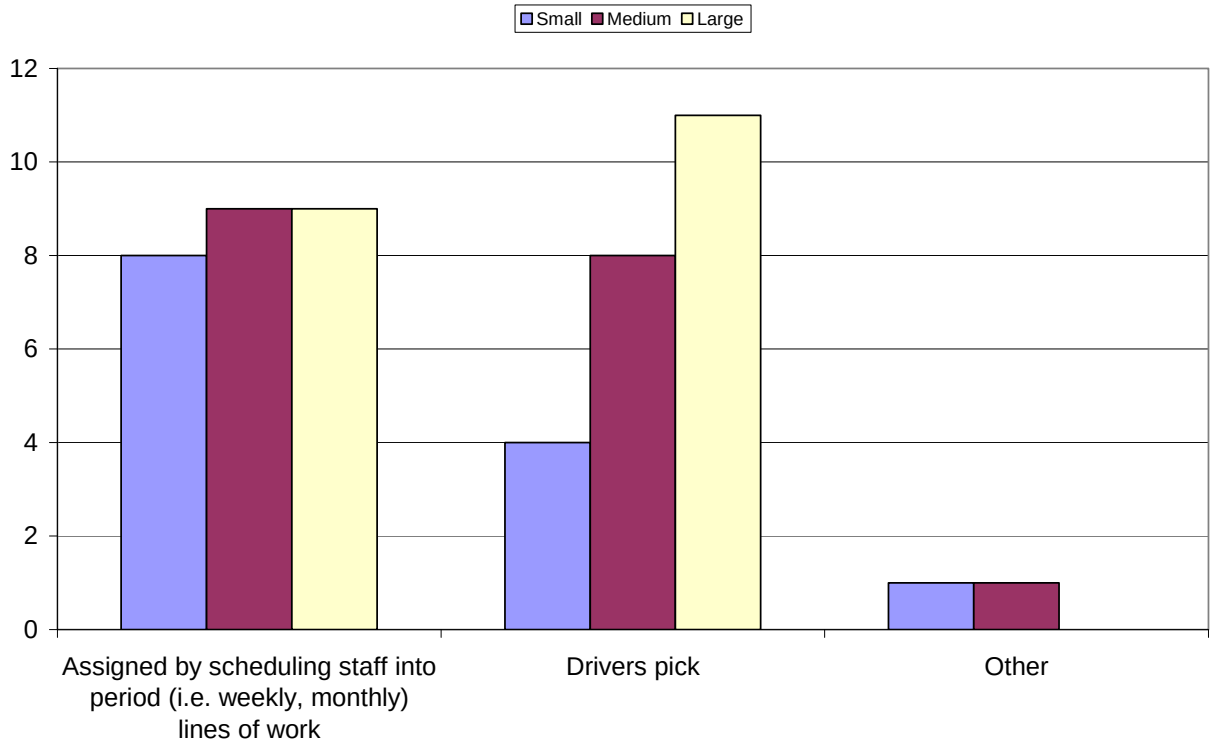
Q147. Do part-time operators pick work or are they assigned work?



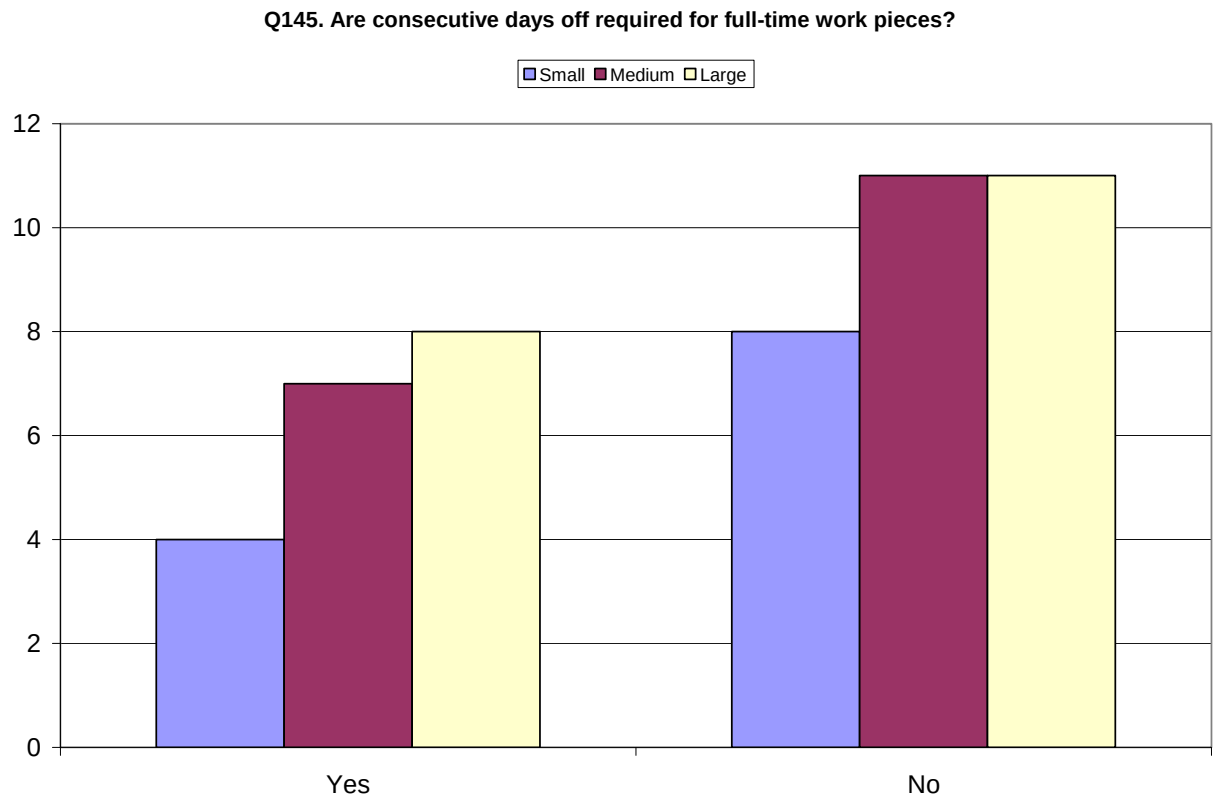
Copyright National Academy of Sciences. All rights reserved.

Treatment of days off split roughly half and half between being assigned and picked (this matches the cafeteria approach). Small agencies were more likely to have days off assigned by staff, in line with their greater tendency toward rostering. Consecutive days off were not required at most agencies (61 percent), yet operators will typically consider this an important part of a 'friendly' roster. At 71 percent of reporting agencies, all operators work the same line of work from week to week; this percentage rose to 84 percent if the extraboard operators were excluded. This indicates few instances of drivers rotating through the lines of work.

Q143. Do drivers pick their days off or are these assigned within each line work?



Copyright National Academy of Sciences. All rights reserved.



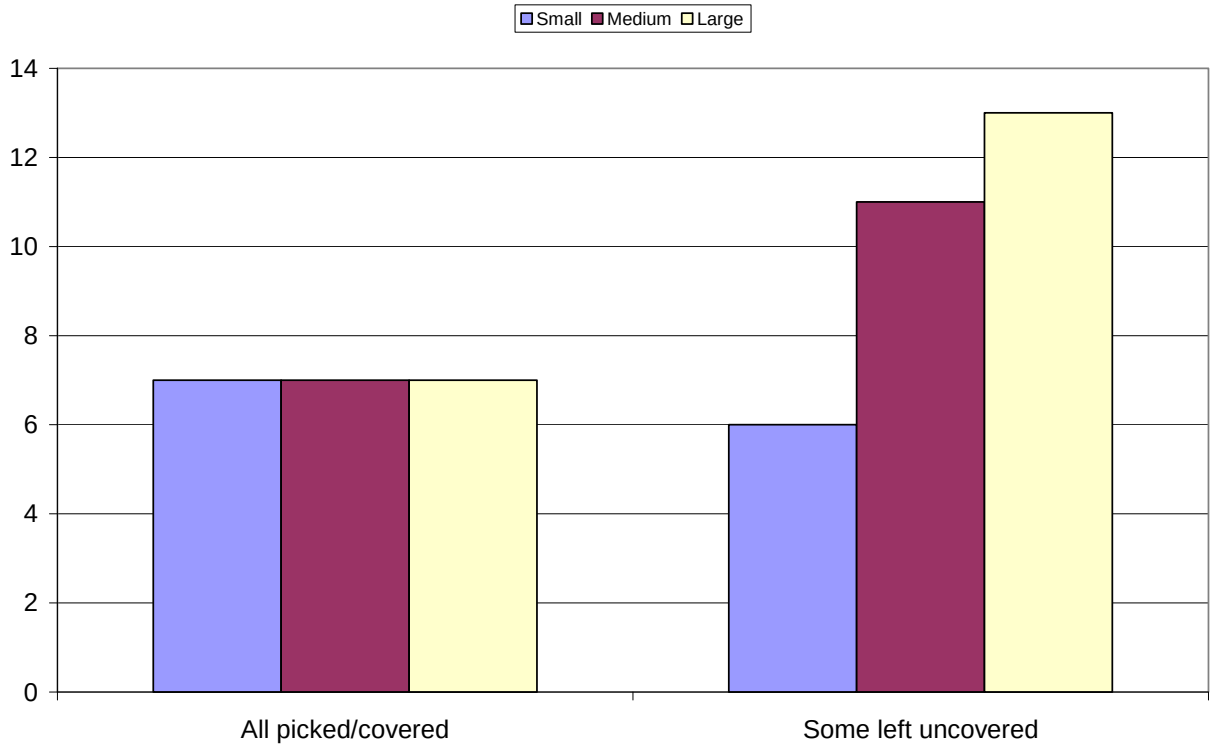
Extraboard/relief components are sized using a range of methods. Almost half of the respondents reported using a percentage of their rosters to size the extraboard, with the most common sizing between 11 and 20 percent. Fourteen percent based extraboard size on the absence rate, and 11 percent used historical numbers. Small agencies were more often based extraboard on qualitative measures like preference, experience, and historical trends while medium and large agencies were more likely to use quantitative measures like percentages of the roster and absence rate. Only one small agency reported that the contract stipulated the size of the extraboard.

141. How is your agency's extraboard/relief component sized?					
	Small	Medium	Large	Total	%
Historical numbers	2	2		4	11%
Management preference	2			2	6%
No extraboard	2	1		3	8%
Based on experience	1	1		2	6%
Based on absence rate		1	4	5	14%
Percentage of roster (under 10%)			1	1	3%
Percentage of roster (11-20%)	2	4	6	12	33%
Percentage of roster (21-30%)		1	3	4	11%
Left over drivers		2		2	6%
Labor agreement		1		1	3%
				36	

Copyright National Academy of Sciences. All rights reserved.

At least some scheduled runs are left for extraboard/relief to cover at about 60 percent of agencies. Half of the agencies where all work is not picked reported that less than five percent of work is left unpicked, and in all cases, less than 15 percent of work is not picked. Leftover work is more often available at medium and large agencies. Often these will be small peak trippers.

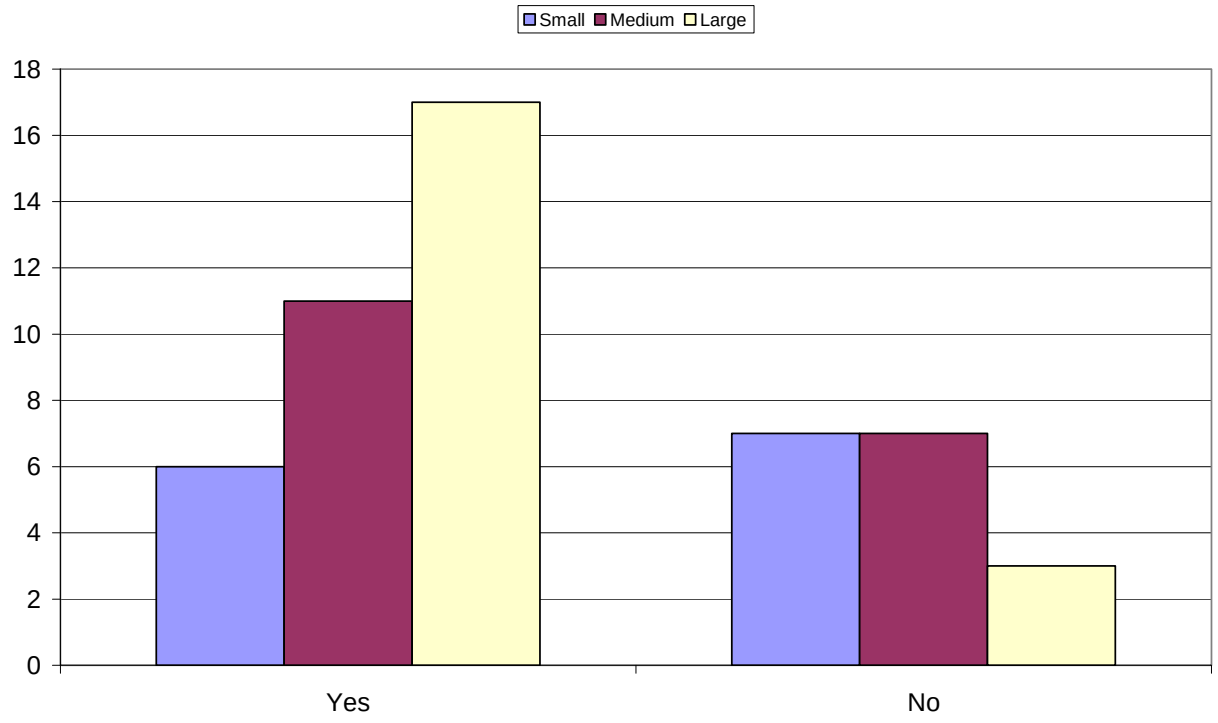
Q151. Is all work picked or is some left for extraboard/relief to cover?



Copyright National Academy of Sciences. All rights reserved.

Operator work assignments can include both extraboard/relief and regular run assignments at two-thirds of the sampled agencies. The practice was much more prevalent at large agencies, with 85 percent of agencies combining the two, while under half of small agencies allow this.

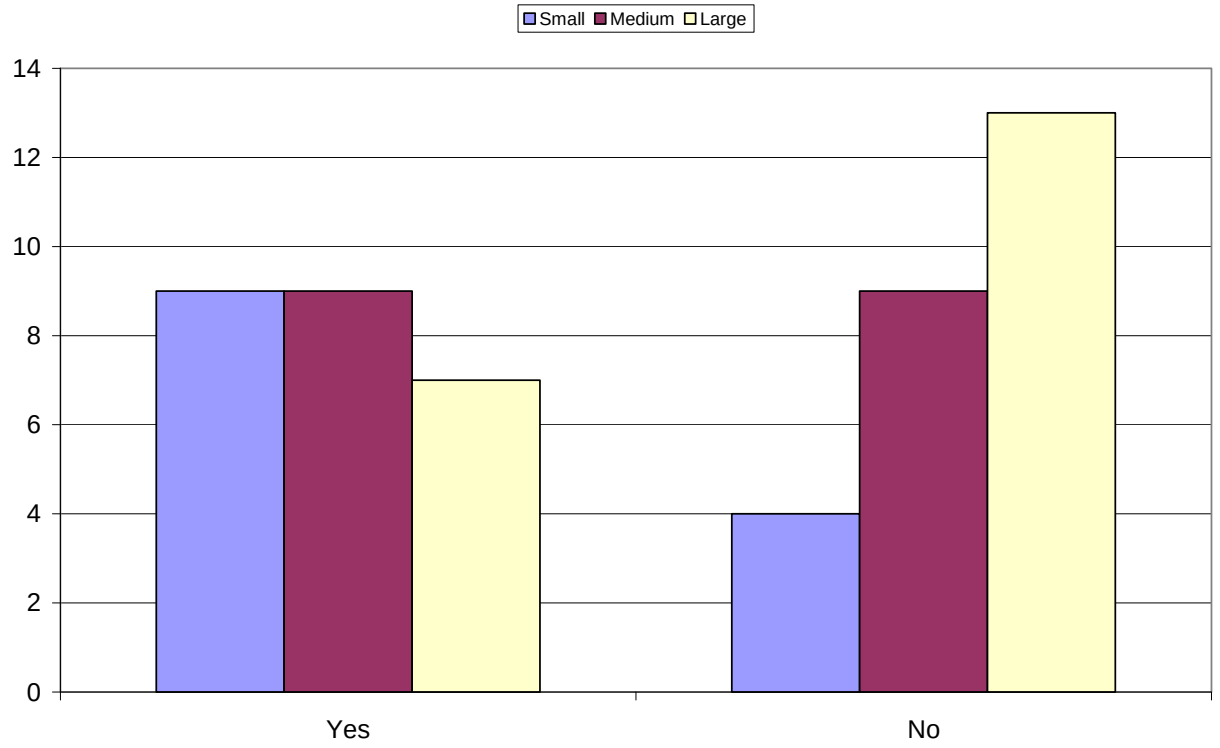
Q146. Can work pieces include a combination of extraboard/relief and regular run assignments?



Copyright National Academy of Sciences. All rights reserved.

Approximately half of the responding agencies allow 4-day work weeks for operators. Small agencies were much more likely to use 4-day work weeks, and large agencies were much less likely to do so. At agencies where 4-day work weeks are allowed, most reported that less than 20 percent of weekly work assignments were 4/10.

Q148. Does your system allow 4-day work weeks for operators?



An overview of the process of posting and selecting work assignments is summarized here. Work assignments are posted anywhere from two to five days to five weeks in advance (one to three weeks was the most common response) and then picked by seniority. Operators are given a certain time to select their work, and might do this in person or by submitting their top three preferences. Several agencies noted that the union must review the work assignments first, and in at least one case the union supervises the pick. Vacated runs are primarily filled through the extraboard (40 percent) or picked through seniority (38 percent).

Respondents were asked about their agencies' view of the optimal use of 4/10, 5/8, and part time operators. Most of the agencies that replied to this question reported that no detailed analysis had been conducted. Based on the responses, there is nothing close to consensus regarding the optimal use or mix. Interesting observations included:

- Operator burn-out is more likely for four-day work weeks
- Differences in work rules (longer runs have longer spreads) may play a role in defining the "optimum" mix
- Need to negotiate better extraboard rules before expanding use of 4/10 work weeks
- Ten-hour runs created only if they reduce overtime
- 4/10 works great for fixed route, 5/8 better for paratransit
- Goal is to keep our runs cut only once; do not want to multi-cut a piece

Copyright National Academy of Sciences. All rights reserved.

- A careful analysis revealed that 4/10 was not effective because it affected blocking of trips to get proper breaks and weekend work did not fit well into the runcut process
- No optimum mix because full-time operators cannot work 4/10
- It is a subject of debate whether the savings from 4/10 are cancelled out by the need to maintain a larger PTO staff to fill open assignments
- When 4/10 assignments approach 12 percent, the advantage is lost
- 40 percent 4/10, 60 percent 5/8, and no PTOs is optimal

Constraints and challenges regarding roster development included the requirement for consecutive days off (yet the majority of agencies reported this was not a labor rule constraint), operator shortages, and minimum time requirements between assignments, as shown below.

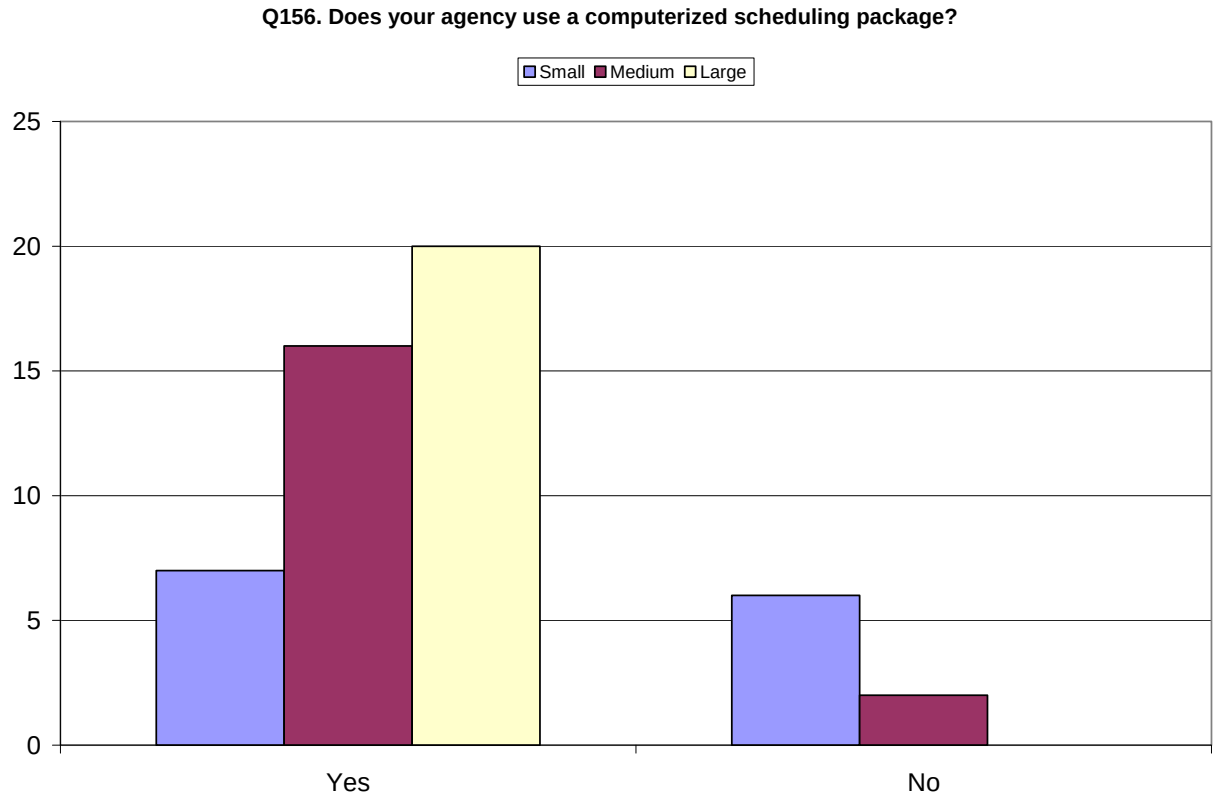
Q155: Please describe any constraints that pose the greatest restriction on roster development.

	Small	Medium	Large	Total	%
Consecutive days off		1	3	4	24%
Operator shortage	1	2		3	18%
Minimum time off between assignments		2	1	3	18%
8-hour daily minimum		1	1	2	12%
40-hour work week	2			2	12%
Holiday work			1	1	6%
Difference in hours on Sunday			1	1	6%
Keep same type of work together			1	1	6%
Number of lines			1	1	6%
Rotating days off		1		1	6%
Selecting runs to mix with weekend work		1		1	6%
Spread penalties		1		1	6%
Straight run requirements		1		1	6%
Tripper		1		1	
Union requests for inefficient work distribution, days off			1	1	6%
	3	8	6	17	

Copyright National Academy of Sciences. All rights reserved.

B.8 Computerized Scheduling

Computerized scheduling and applications are becoming more commonplace and agencies that use computerized packages reported an improved scheduling process. Computerized scheduling packages are commonplace at medium and large agencies surveyed, and at a slight majority of small agencies surveyed. Across all responding agencies, 84 percent utilize a computerized scheduling system.



Copyright National Academy of Sciences. All rights reserved.

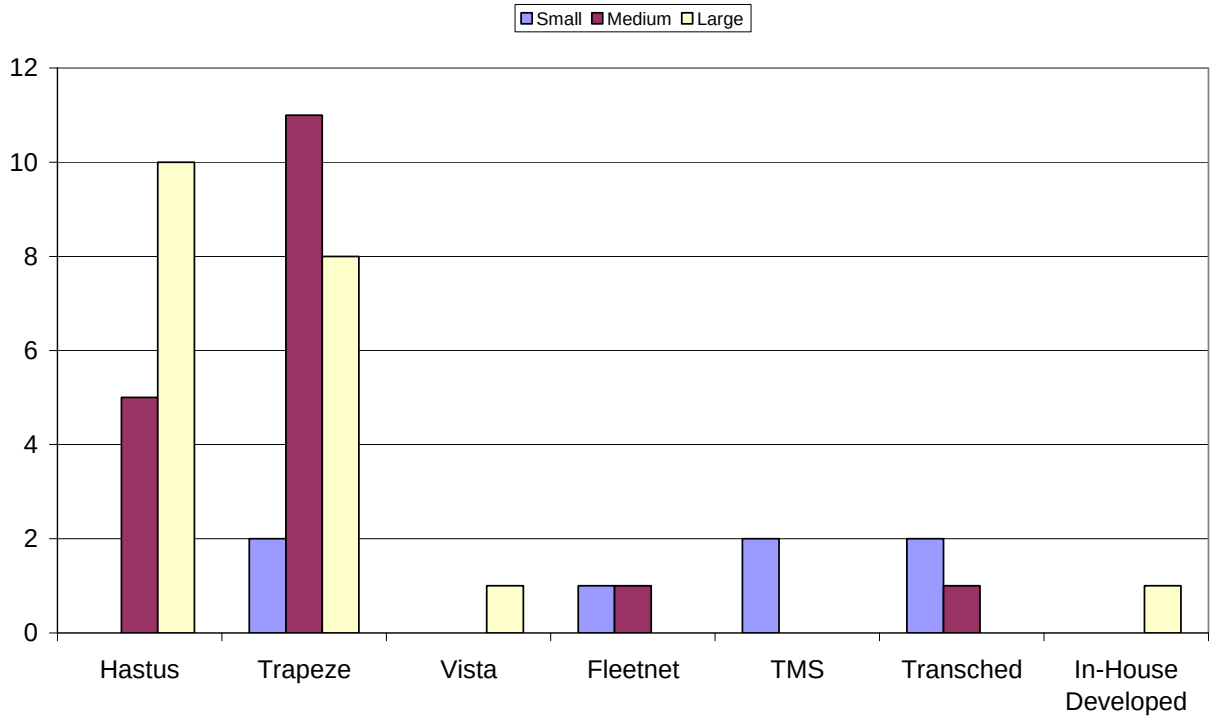
The most obvious reported benefit of scheduling software is the automation of tasks. The three most automated tasks in all modes surveyed (bus, light rail, and heavy rail) were runcutting, blocking, and building trip tables.

Q164. Please indicate which parts of the scheduling process have been automated - by mode, where feasible					
Bus	Small	Medium	Large	Total	%
Planning routes	2	1	4	7	16%
Developing running times	1	3	8	12	27%
Building trip tables	4	13	18	35	80%
Blocking	6	14	15	35	80%
Runcutting	6	14	18	38	86%
Rostering	5	5	10	20	45%
Managing the sign-up	3	8	10	21	48%
Extraboard sizing	1	2	1	4	9%
Part-time operator assignment	2	3	5	10	23%
Traffic data collection	0	5	5	10	23%
Daily crew assignment/absentee management	12	5	3	20	45%
Daily dispatching	8	9	4	21	48%
				44	
LRT	Small	Medium	Large	Total	%
Planning routes			1	1	7%
Developing running times		1	3	4	29%
Building trip tables		3	10	13	93%
Blocking		3	8	11	79%
Runcutting		3	10	13	93%
Rostering		2	3	5	36%
Managing the sign-up		1	5	6	43%
Extraboard sizing				0	0%
Part-time operator assignment		1	2	3	21%
Traffic data collection		1	3	4	29%
Daily crew assignment/absentee management		1	5	6	43%
Daily dispatching		1	5	6	43%
				14	
Heavy Rail	Small	Medium	Large	Total	%
Planning routes			1	1	13%
Developing running times			1	1	13%
Building trip tables			7	7	88%
Blocking			6	6	75%
Runcutting			7	7	88%
Rostering			3	3	38%
Managing the sign-up			5	5	63%
Extraboard sizing			1	1	13%
Part-time operator assignment			2	2	25%
Traffic data collection			2	2	25%
Daily crew assignment/absentee management			4	4	50%
Daily dispatching			4	4	50%
				8	

Copyright National Academy of Sciences. All rights reserved.

Trapeze and Hastus were the most frequently mentioned scheduling software packages. Almost two-thirds of the medium sized agencies reported use of Trapeze (two use more than one program), while half of the large agencies use Hastus. Small agencies reported a variety of scheduling software packages. Popular modules purchased with the software include Trapeze FX, OPS, and PASS.

Q157. If your agency uses a computerized scheduling package, what software package is used?



Copyright National Academy of Sciences. All rights reserved.

Most scheduling software was procured since 1990. Original procurement dates of computerized scheduling packages suggest a gradual spread in use of these packages from large to medium and small agencies (with a few early-adopter exceptions among small agencies). Upgrades to software have also occurred recently, with over 80 percent of small and medium agencies and 70 percent of large agencies purchasing upgrades after 2004.

Q158. When was it originally procured?

	Small	Medium	Large	Total	%
Before 1980			1	1	2%
1980-1989	2		6	8	19%
1990-1995	1	5	5	11	26%
1996-2000	1	5	4	10	23%
2001-2007	3	6	4	13	30%
	7	16	20	43	

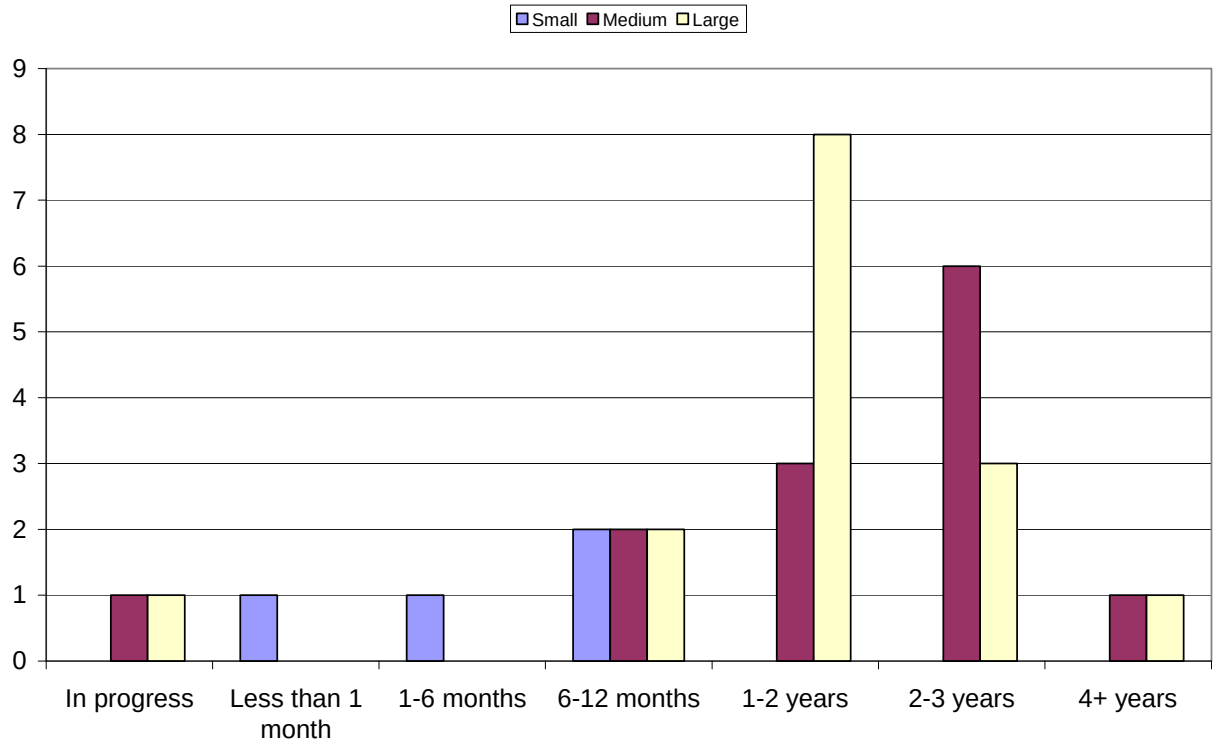
160. When did your agency last upgrade?

	Small	Medium	Large	Total	%
2007-In progress		5	5	10	24%
2005-2006	5	8	9	22	52%
2003-2004		2	3	5	12%
2001-2002			1	1	2%
1997-2000			1	1	2%
None	1	1	1	3	7%
	6	16	20	42	

Copyright National Academy of Sciences. All rights reserved.

Implementation is not a simple process. Over two-thirds of responding agencies reported a timeline of at least one year from signed contract to implementation of the scheduling software. Small agencies were the exception: all reported a timeline of less than one year.

Q162. How long (from signed contract) die the original implementation project take place?



The use of scheduling software is not limited to schedulers, as many packages have modules that can be useful for planning, data analysis, and daily operations and dispatch. Three-fourths of the operators who had automated scheduling systems indicated that other departments use their system. Use by others is more prevalent in medium and large agencies than in small ones (under 50 percent at small agencies). The most common applications by other departments include daily operations and dispatch management, mapping, long term planning, and absence management. Other uses include customer information, NTD reporting, and trip planning.

Q167: By Whom?					
	Small	Medium	Large	Total	%
APCs		1	1	2	6%
Control Room supervisors			1	1	3%
Customer Service		3	1	4	13%
Garage supervisors	1			1	3%
GIS			1	1	3%
Information	1	1	1	3	9%
Maintenance	2			2	6%
Marketing			1	1	3%
Operations	2	8	3	13	41%
Operations-Dispatch		1	2	3	9%

Copyright National Academy of Sciences. All rights reserved.

Paratransit personnel		3		3	9%
Payroll		1		1	3%
Planning		7	9	16	50%
Software Analyst		1		1	3%
Station Clerks		1		1	3%
Traffic checking			1	1	3%
	3	14	15	32	

A major constraint on using computerized scheduling packages is the cost of purchasing the software and training staff. We received fewer than 15 responses to cost-related questions, so the reader should not interpret these findings as definitive. Original software license and training costs ranged from under $50,000 to greater than $1.5 million. Small agencies spent under $500,000 on their software whereas large agencies spent over $500,000 in all circumstances.

Q163. Please provide the approximate cost for: Original software license & training					
	Small	Medium	Large	Total	%
Less than $50,000	2			2	17%
$50,000 - $99,999		1		1	8%
$100,000 - $499,999	1	1		2	17%
$500,000 - $999,999		3	2	5	42%
$1,000,000 - $1,499,999			1	1	8%
$1,500,000+		1		1	8%
				12	

In addition to initial procurement and startup costs, an annual maintenance cost is also associated with the software. Maintenance costs for large agencies range from $50,000 to $125,000 annually (normally 10 to 15 percent of the license fee). For small agencies, these costs are under $25,000 annually, while medium agencies pay between $10,000 and $100,000 for software maintenance. The survey also included questions on the cost of software implementation and software upgrades, but fewer than five agencies responded to these questions.

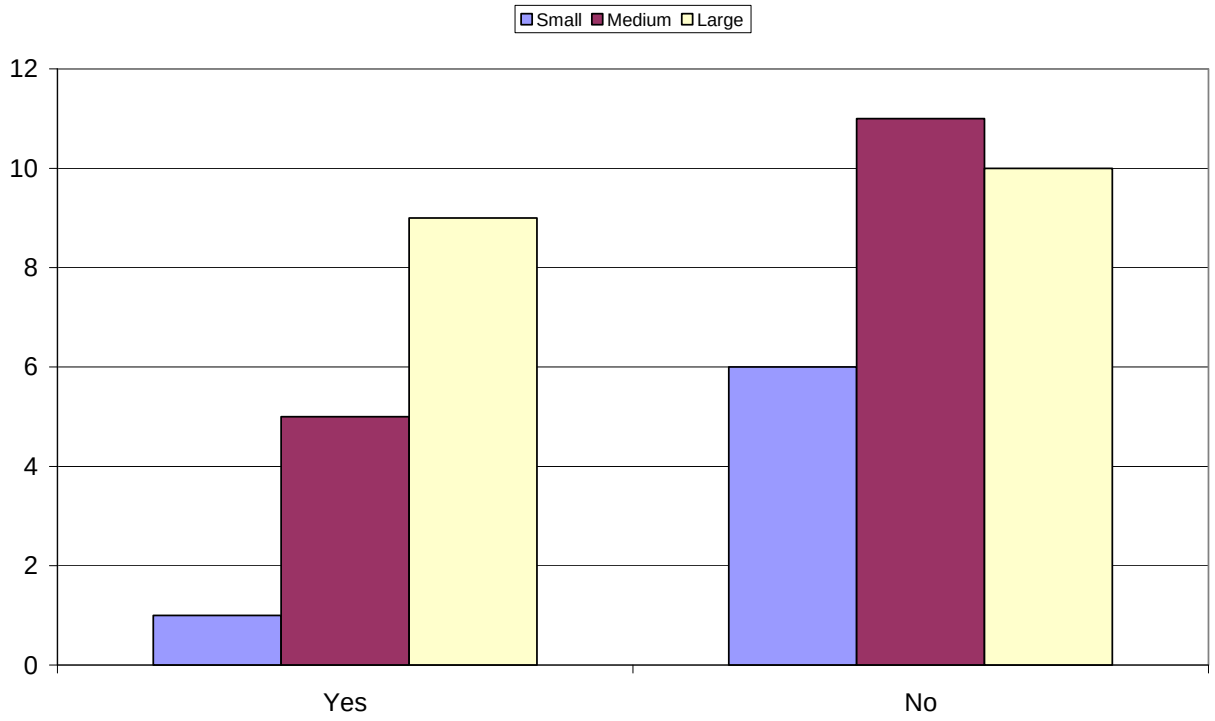
Q163. Please provide the approximate cost for: Software maintenance (annual cost)					
	Small	Medium	Large	Total	%
Less than $10,000	2			2	14%
$10,000 - $24,999	1	2		3	21%
$25,000 - $49,999		1		1	7%
$50,000 - $74,999		3	1	4	29%
$75,000 - $99,999		1	1	2	14%
$100,000 - $125,000			2	2	14%
				14	

Nearly two-thirds of responding agencies (even a slight majority of large agencies) have not calculated savings related to the implementation of computerized scheduling. This is an interesting outcome, given that in many instances the basis for the expenditure would be

Copyright National Academy of Sciences. All rights reserved.

potential cost savings. Those few agencies that have conducted estimates reported a range of annual savings from $7 million for large agencies to $300,000 for medium sized agencies and $8,000 for small agencies. Overall, the savings amounted to less than 3% of the total operating budget.

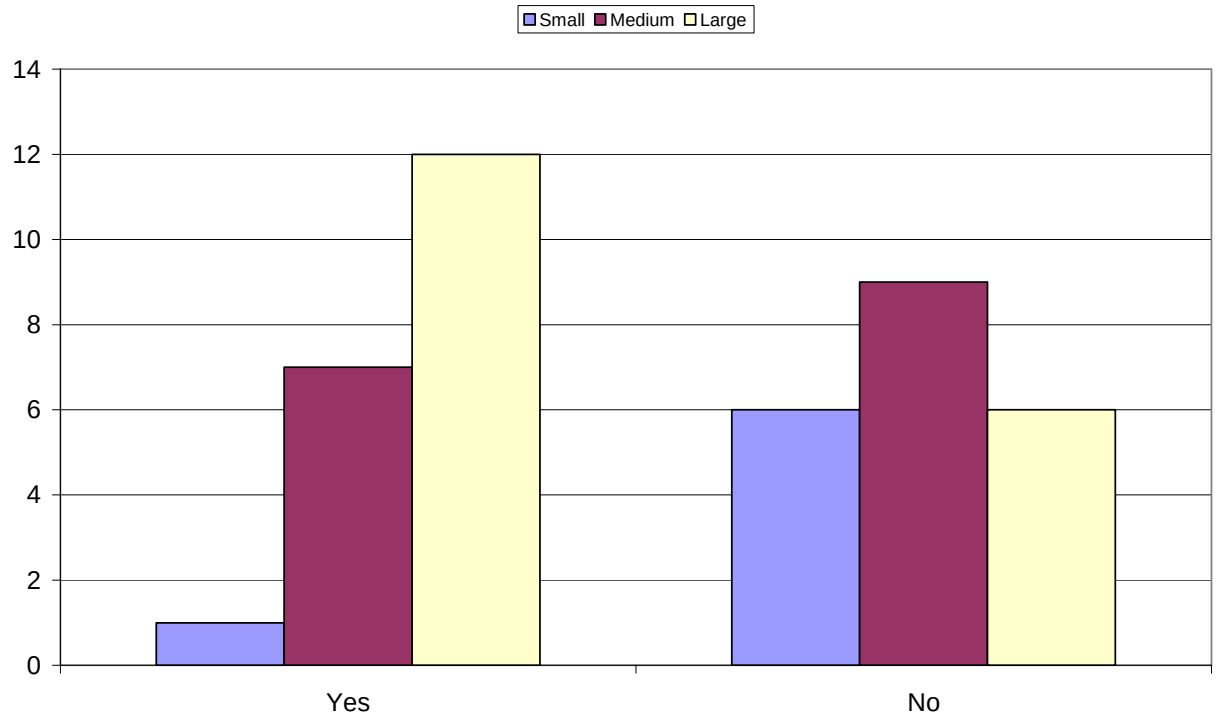
Q165. Has your agency calculated savigns directly attributable to implementation of computerized scheduling software (formally or informally)?



Copyright National Academy of Sciences. All rights reserved.

Large agencies especially were more likely to assess non-economic impacts of the implementation of computerized scheduling. A range of benefits was reported, as shown below. The most common benefit was more efficient scheduling.

Q171. Has your agency assessed other benefits and/or efficiency impacts resulting from implementation of computerized scheduling software?

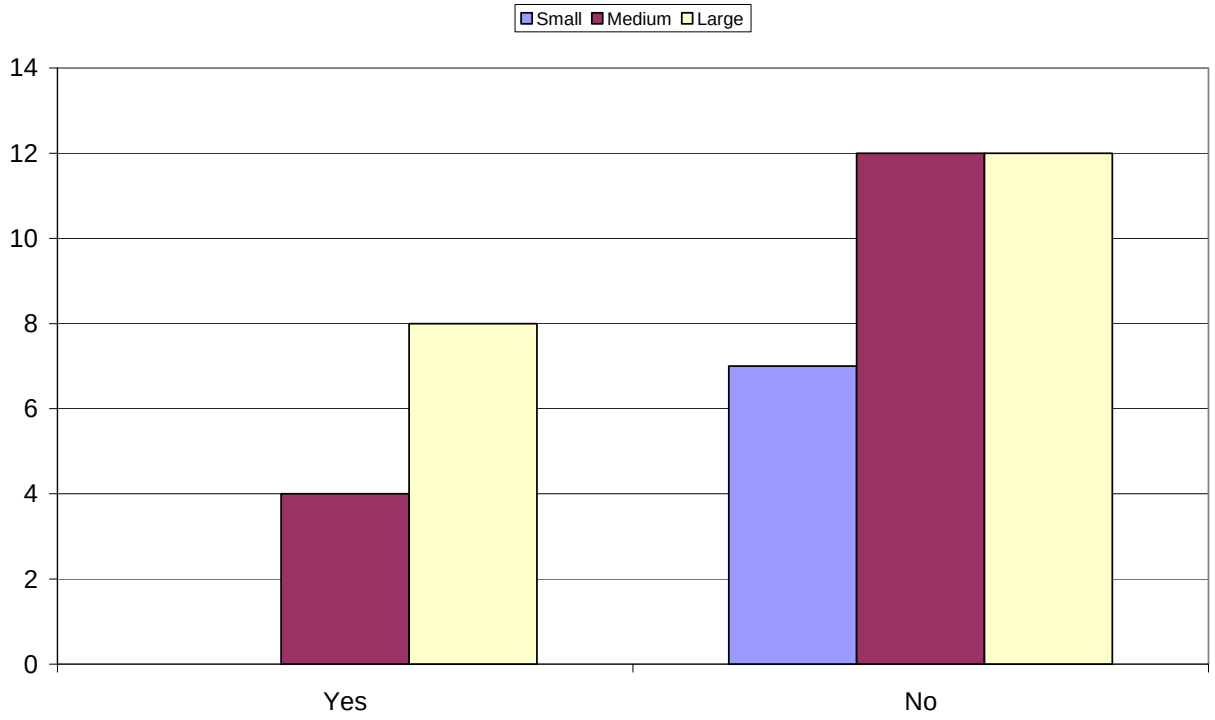


171a. Please describe.					
	Small	Medium	Large	Total	%
Better data reporting	1	1	3	5	28%
Data integration from multiple systems		1	2	3	17%
Improved accuracy	1		2	3	17%
Less overtime			1	1	6%
More efficient scheduling	1	1	6	8	44%
Quicker planning analysis			2	2	11%
Quicker turnaround		2	3	5	28%
Streamlined electronic mapping, AVL & APC		2	2	4	22%
				18	

Copyright National Academy of Sciences. All rights reserved.

The benefits of computerized scheduling have altered the size of scheduling departments in only one-third of the responding agencies. Again, initial expectations for computerized scheduling procurements were often based upon some reduction in scheduling department size. Small agencies did not encounter any change in size, due to the minimal size of the scheduling staff to begin with. In two medium sized agencies, the implementation of scheduling software actually led to an increase in scheduling staff by one person. Staffing decreases were seen mostly in large agencies, with a typical reduction of between five and ten positions.

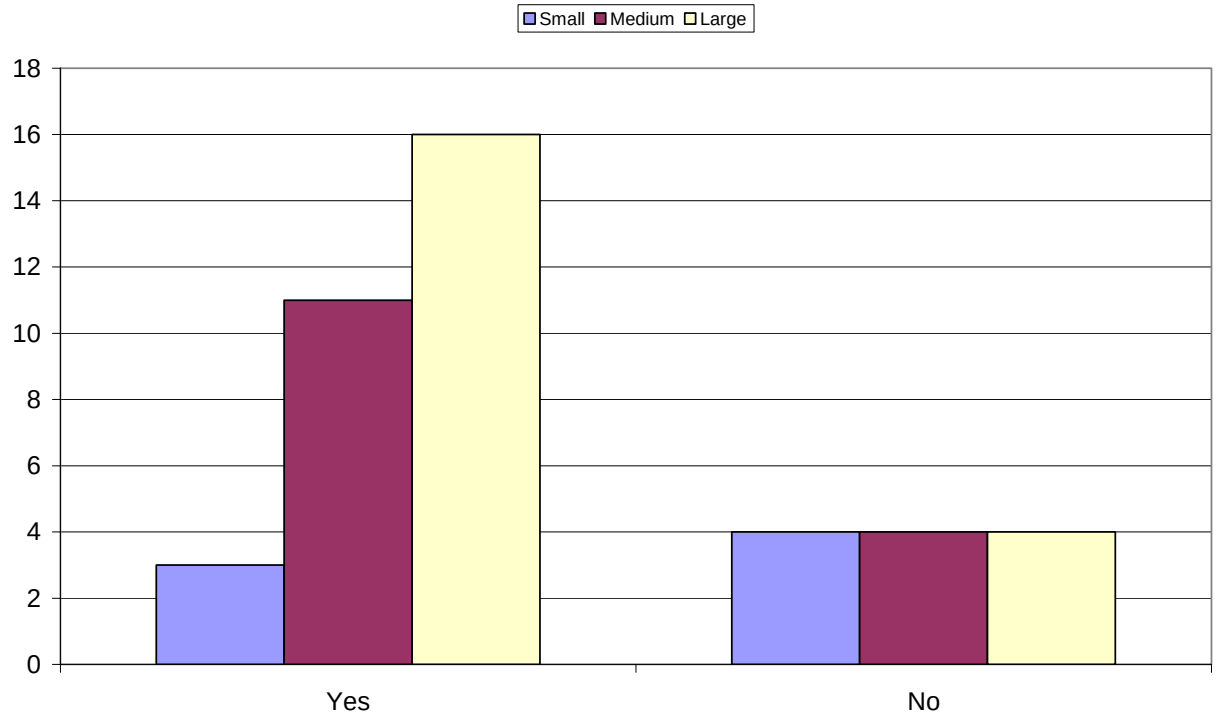
Q172. Has the size of your agancy's scheduling department changed as a direct result of implementation of computerized scheduling software?



Copyright National Academy of Sciences. All rights reserved.

Computerized scheduling packages have changed the time it takes to produce and implement schedule at most agencies (71 percent), particularly at large and medium agencies. Other than one large agency reporting a time increase due to the increased number of tasks associated with using the software, agencies have achieved time savings from automation. Of responding agencies, 38 percent stated the time to produce and implement schedules has decreased by 50 percent. Other changes were not as dramatic, but ranged from a few days to weeks.

Q175. Has the time it takes your agency to produce and implement schedules changed as a direct result of implementation of computerized scheduling software?

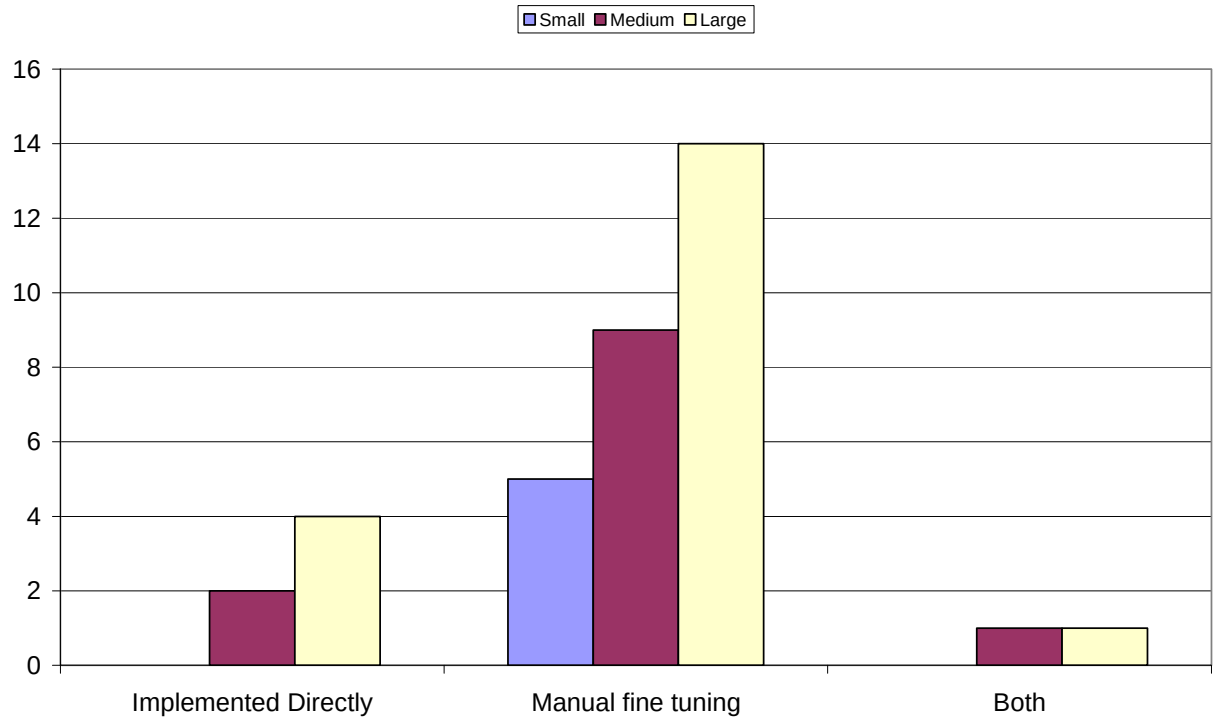


The time reduction in producing and implementing schedules has led to increased expectations placed on scheduling departments. Nearly 80 percent of all responding agencies and 95 percent of large agencies reported increased expectations regarding turnaround time and the volume of “what-if” tasks.

Copyright National Academy of Sciences. All rights reserved.

One of the more interesting findings from the survey was the continued reliance on manual fine-tuning of the computerized scheduling solutions. Over 80 percent of respondents reported at least some manual fine-tuning of the software package results prior to implementation.

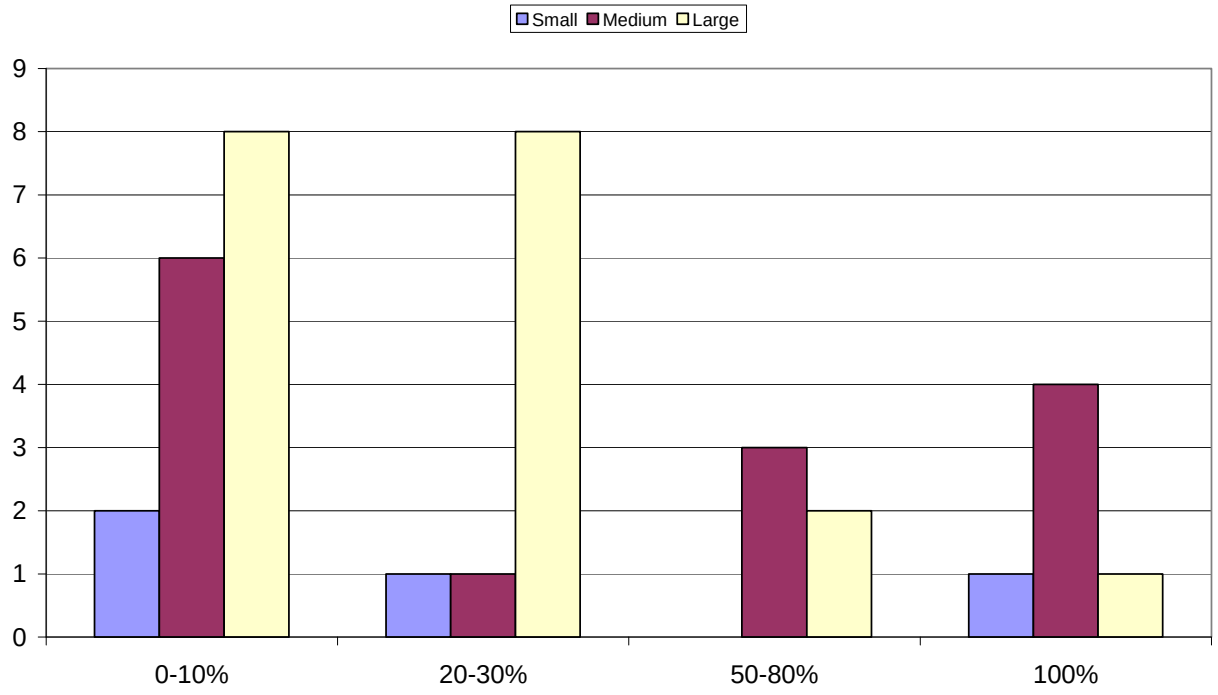
Q170. To what extent are the solutions produced by your computerized system utilized (i.e. are they implemented directly, or do they require manual fine-tuning)?



Copyright National Academy of Sciences. All rights reserved.

This finding strongly underlines the continued requirement for schedulers to maintain experience in manual scheduling techniques. At the majority of agencies, however, less than 30 percent of the scheduling staff did manual scheduling prior to implementation of computerized scheduling.

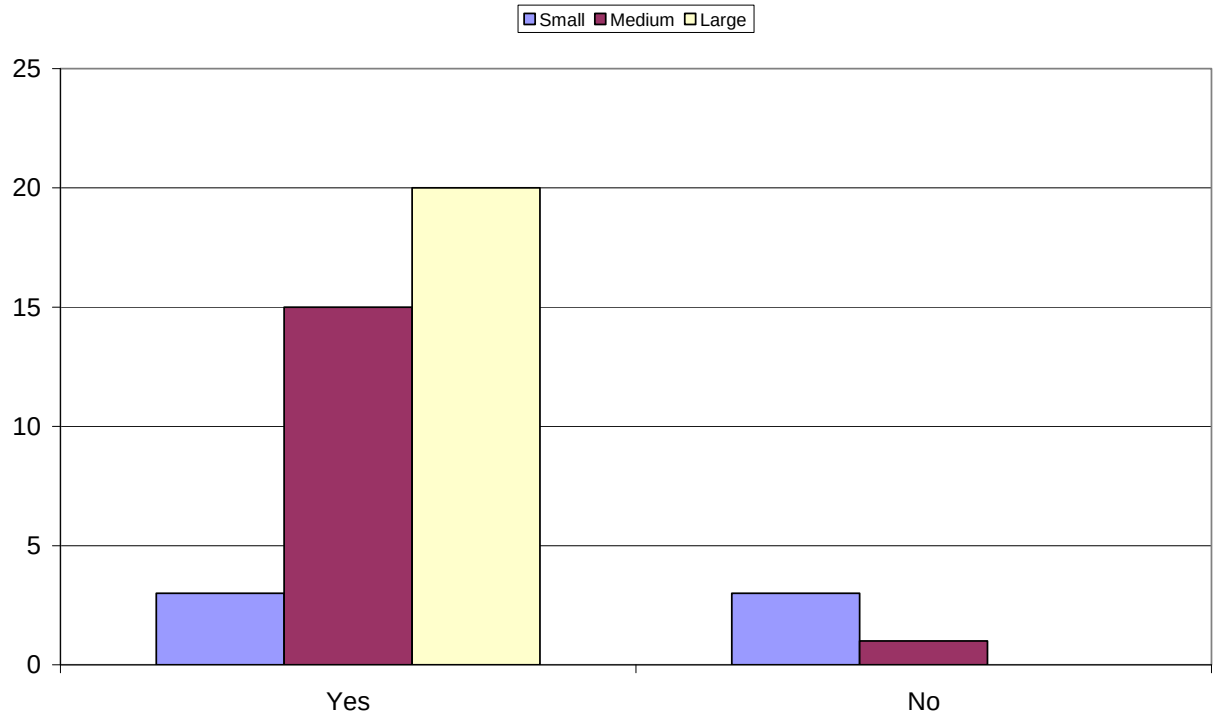
Q174. What percentage of the current scheduling department staff did manual scheduling (at your agency or another agency) prior to the implementation of computerized scheduling software?



Copyright National Academy of Sciences. All rights reserved.

Scheduling software is interfaced with other data systems at most agencies. With larger amounts of data and staff, medium and large agencies are more likely to have software interfaced among other departments. The most common interfaces are with payroll, AVL, dispatch, APC, and customer service. This integration changes the role of the scheduling department, which often now has broader responsibility for database management.

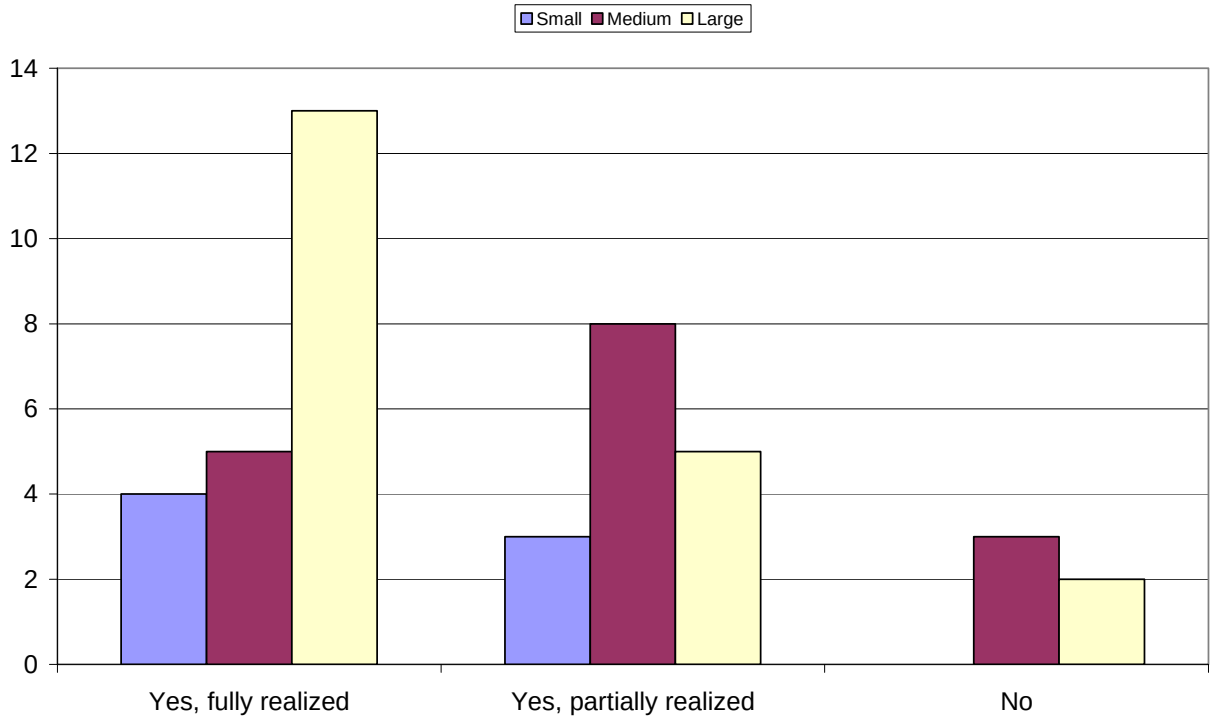
Q180. Does your agency's computerized scheduling software interface with other agency data systems?



Copyright National Academy of Sciences. All rights reserved.

The survey asked respondents if the expected benefits of implementing computerized scheduling software have been realized. A slight majority reported that the benefits have been fully realized, but 37 percent reported only partial realization and 12 percent answered no. Respondents raised several issues in explaining why benefits have been partially realized or not realized at all. These suggest that the acquisition of a computerized scheduling package, while offering many benefits, by itself is not always an immediate panacea.

Q178. Overall, have the estimated benefits of implementing computerized scheduling been realized?



Copyright National Academy of Sciences. All rights reserved.

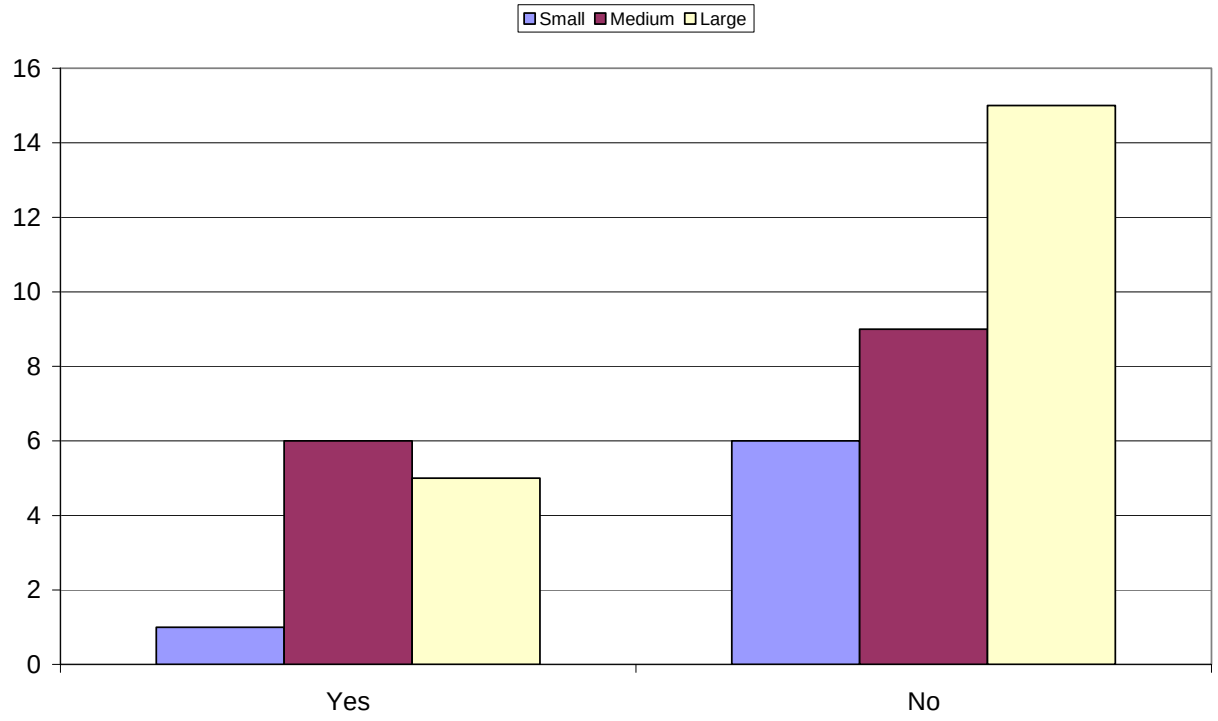
Q179. If your agency has not realized or has only partially realized the benefits from computerized scheduling, describe any related issues.					
	Small	Medium	Large	Total	%
Crew scheduling optimized but not vehicle scheduling			1	1	6%
Customer support is a problem			1	1	6%
Software is bug prone			1	1	6%
PC versions slower and not as good as older DOS versions			1	1	6%
Training staff is difficult		2	1	3	17%
AVL and APC unable to integrate into the software - upgrading currently			1	1	6%
Runcutting still needs to be reviewed and changed manually		1	1	2	11%
Runcutting module is unsupported and unmaintained			1	1	6%
Crew scheduling still done manually			1	1	6%
Reporting software is poor			1	1	6%
Unions slow to accept new technology and efficiency		1		1	6%
Manual scheduling still necessary at times		1		1	6%
Increased parameters makes the process longer		1		1	6%
Not fully installed due to payroll problems		1		1	6%
Do not use all modules	1			1	6%
Difficult to know since multiple departments using software	1			1	6%
Would like to have optimization in all phases of the process.	1			1	6%
				18	

The survey also asked whether agencies had switched from one computerized scheduling package to another within the past two years. Only 14 percent of respondents reported a switch. Almost all agencies that switched had purchased their original software prior to 1995. The inability of older software to integrate with other functions was the primary reason for changing. Most of these agencies reported that the expected benefits had been realized. Agencies that had not realized the expected benefits cited an ongoing implementation process.

Copyright National Academy of Sciences. All rights reserved.

The increasing integration of scheduling software with other agency functions data systems raises the issue of whether this integration would preclude consideration of a change in scheduling package. Almost three-quarters of respondents did not see this as an issue. One agency that was concerned about this issue noted that the scheduling department did not have control over the software because multiple departments are involved. Another answered that it took years to get the bugs out of the program, and to change now would be difficult.

Q190. Does the integration of your current computerized scheduling software with other agency functions preclude consideration of a change in scheduling packages?



Most agencies not using computerized scheduling software rely on spreadsheets (71 percent). Other methods used were a word processor and an agency created system for reporting and data organization.

192. If not using computerized scheduling software what general software tool does your agency primarily use to build schedules?

	Small	Medium	Large	Total	%
Spreadsheet	4	1		5	71%
Home-grown system without optimizer		1		1	14%
Database				0	0%
Word processor	1			1	14%
				7	

B.9 Scheduling Organization

Scheduling departments are often units within one of two larger departments: Operations (47 percent) and Planning (40 percent). Large agencies had more variety in terms of the location of

Copyright National Academy of Sciences. All rights reserved.

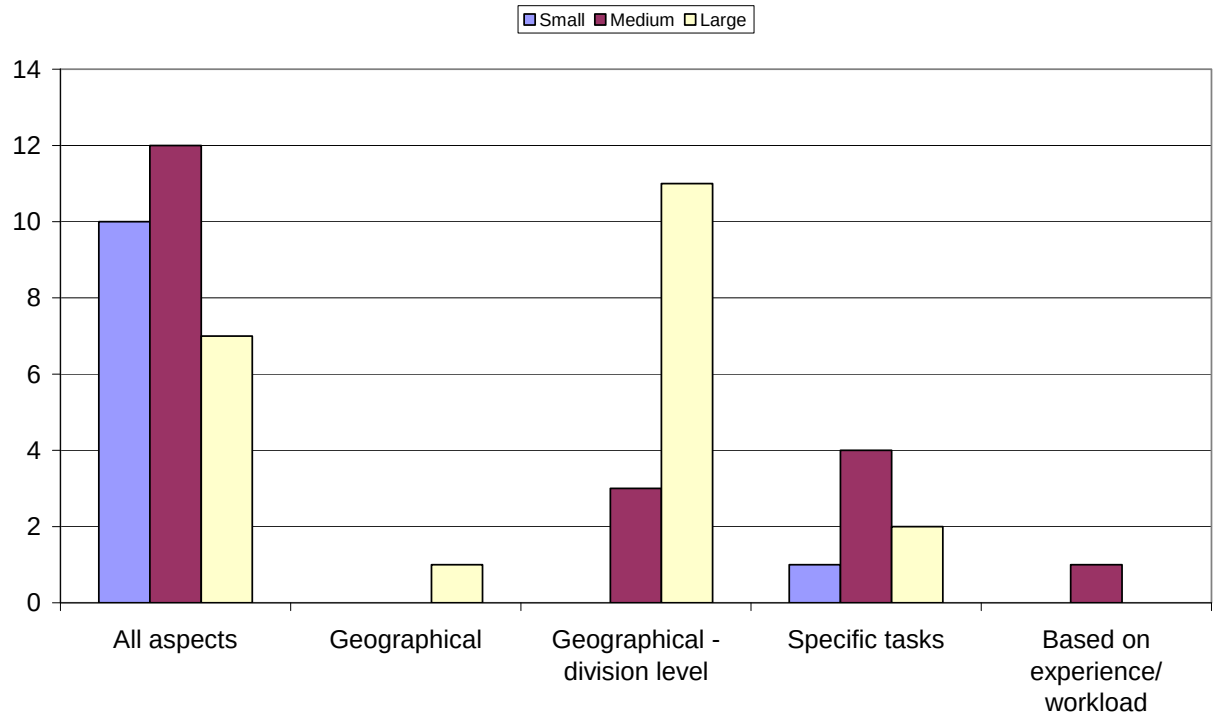
scheduling: Customer Service, Finance, and Business Development were all mentioned. Scheduling departments varied in size between having no dedicated staff to 70 employees (New York City Transit). Most large agencies had over 10 full time employees devoted to scheduling while medium sized agencies had mostly between 1 and 5 employees. 14 small agencies (60 percent) had less than 1 FTE for scheduling.

Almost half of medium sized agencies responded that their scheduling function is understaffed while fewer than 30 percent of small and large agencies did. Workload was the most common method (39 percent) used to determine manpower requirements for the scheduling department, followed by historical levels (18 percent), and no process (14 percent). Only eight percent based manpower requirements on budget, suggesting that budgets are generally derived from existing manpower.

Only three agencies outsource some or all of their scheduling function. Two of the three agencies are small operators that do not have scheduling capability in house and outsource as a matter of business practice. One large agency outsources some scheduling tasks because it is understaffed.

Almost 90 percent of agencies (including those that assign schedulers geographically) reported that their schedulers work across all aspects of scheduling (trip building, blocking, run cutting and rostering). When schedulers have separate duties, they most are most often divided into groups geographically (by operating division) or by mode, and not by functionally. This is most common in large agencies, which are most likely to have multiple modes or garages. Small agencies almost exclusively have schedulers work on all aspects of scheduling. Only 14 percent of agencies reported that schedulers are specialized in specific tasks.

Q37. Do schedules work across all aspects of scheduling or do they work within specific tasks (e.g. runcutting only? or within geographic regions (e.g. one division only)?



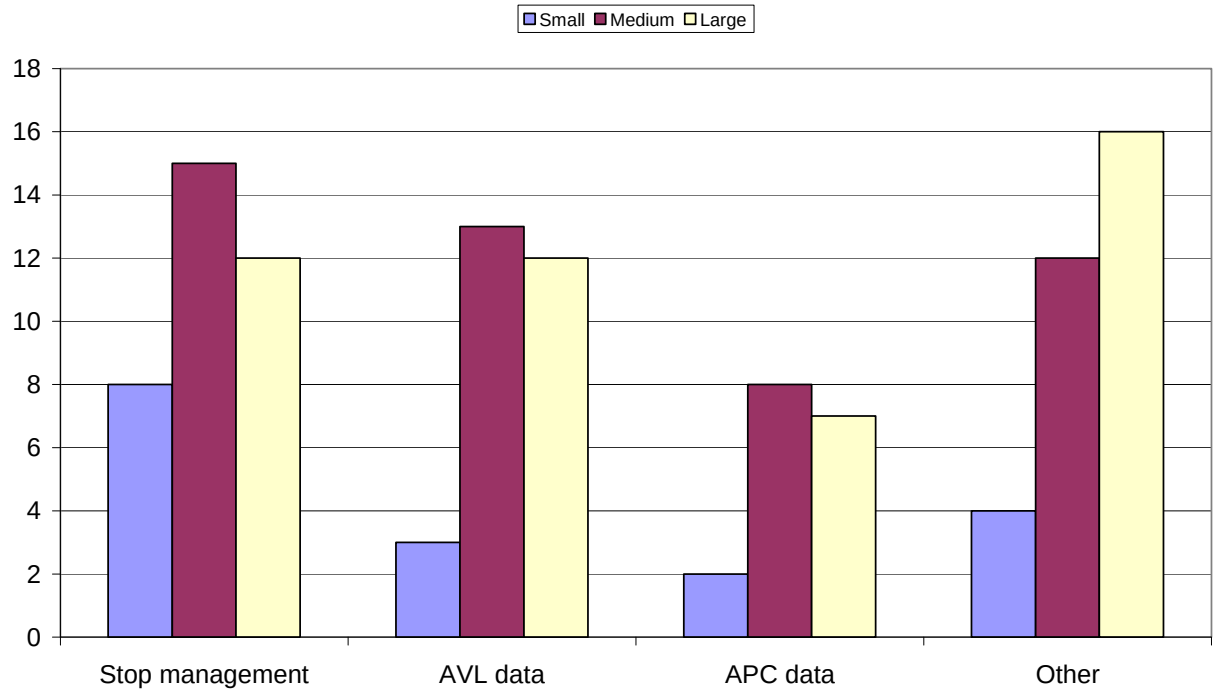
Copyright National Academy of Sciences. All rights reserved.

A typical breakdown of staff time allocation in scheduling departments, based on the normalized average of all responses, has schedule writing and blocking accounting for 31 percent of staff time, while period rostering accounts for only eight percent. The most common "Other" tasks included data analysis and report writing, crew schedules, exception scheduling, and service planning. A majority of agencies report that over 80 percent of scheduling tasks are actually implemented, as opposed to being carried out purely for costing or evaluation purposes.

44. Describe the breakdown of scheduling staff time allocation (in percentage terms):	
	Normalized percentage
Schedule writing & blocking	31%
Runcutting	17%
Period rostering	8%
Run times & ridership data analysis	16%
Data management for downstream systems	12%
Other	17%
	100%

In addition to core scheduling tasks, many scheduling departments are increasingly performing other tasks related to interfaces with other departments. "Other" tasks include developing timetables, collecting and analyzing data (AVL, APC, etc.), managing the bid process, preparing driver cards and paddles, and providing customer information like bus stop announcements.

Q42. If we define "core" scheduling tasks as schedule writing blocking runcutting and rostering are any of the following non-core tasks being undertaken within the scheduling department to meet the requirements of interfacing with other departments?

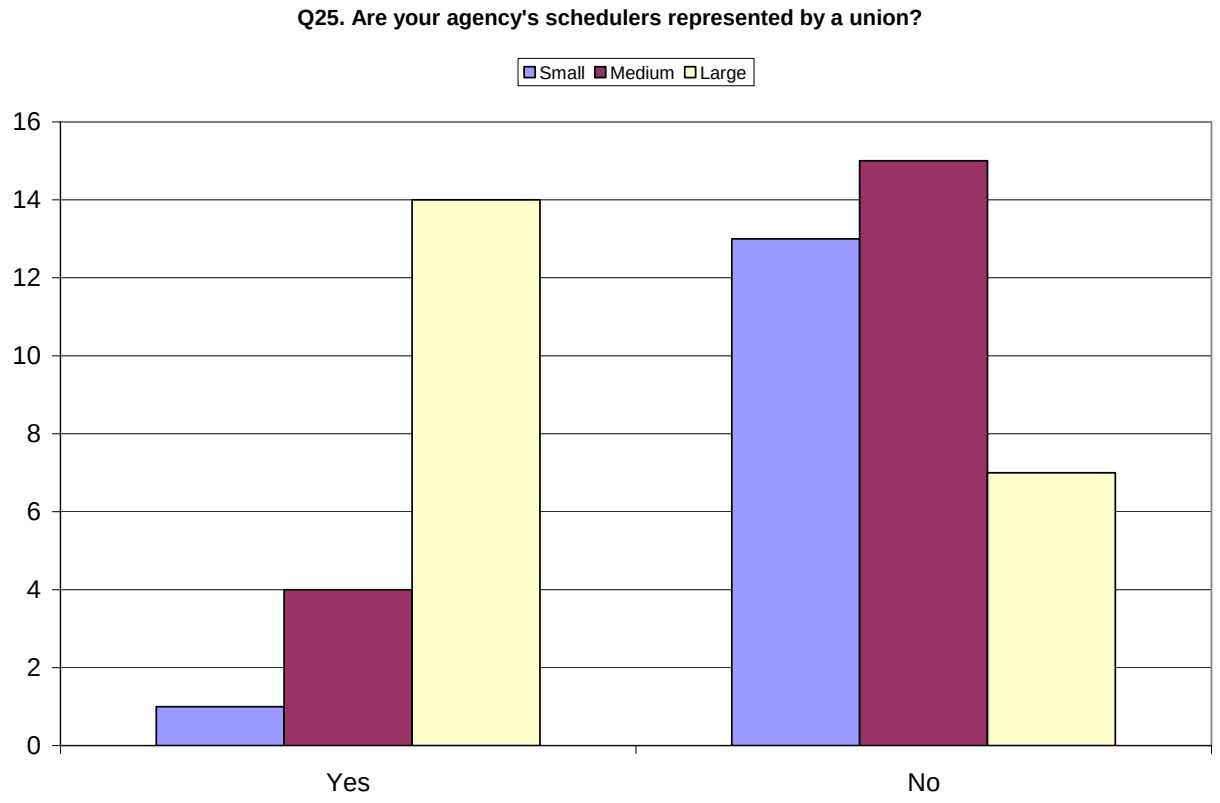


Copyright National Academy of Sciences. All rights reserved.

These added tasks are often related to downstream data requirements. Even smaller agencies are likely to have multiple downstream requirements for scheduling outputs.

43. Describe any downstream data requirements for scheduling outputs at your agency					
	Small	Medium	Large	Total	%
Stop inventory	8	15	20	43	83%
AVL data	3	13	21	37	71%
APC data	3	9	14	26	50%
GIS	5	10	16	31	60%
Telephone information	9	13	19	41	79%
Public timetables	12	18	21	51	98%
Itinerary planning	6	14	18	38	73%
Bus stop schedules	6	13	19	38	73%
Other (please describe)	5	4	13	22	42%

Union representation for schedulers is much more common at large agencies. Approximately half of the unionized schedulers are in the same union as vehicle operators.



Schedulers are primarily recruited internally (70 percent of responding agencies). Many agencies post scheduler jobs externally via trade publications and their own websites. Only 36 percent of agencies require a four-year college degree for their schedulers and another 36 percent have no degree requirement. Over half of agencies prefer their schedulers to have a background in operations, followed by 15 percent who look for a background in planning and

Copyright National Academy of Sciences. All rights reserved.

another 15 percent who look specifically for vehicle operators. No agencies consider a math or operations research background as a major preference.

Mentoring with a more experienced scheduler is the most common training technique for new schedulers, used at 70 percent of responding agencies. Hands-on training is considered necessary to learn how to develop schedules and utilize the software. Almost 40 percent of respondents have in-house training programs to teach new hires about scheduling and 30 percent send new schedulers to outside training classes including Canadian Urban Transit Association and software vendor training courses.

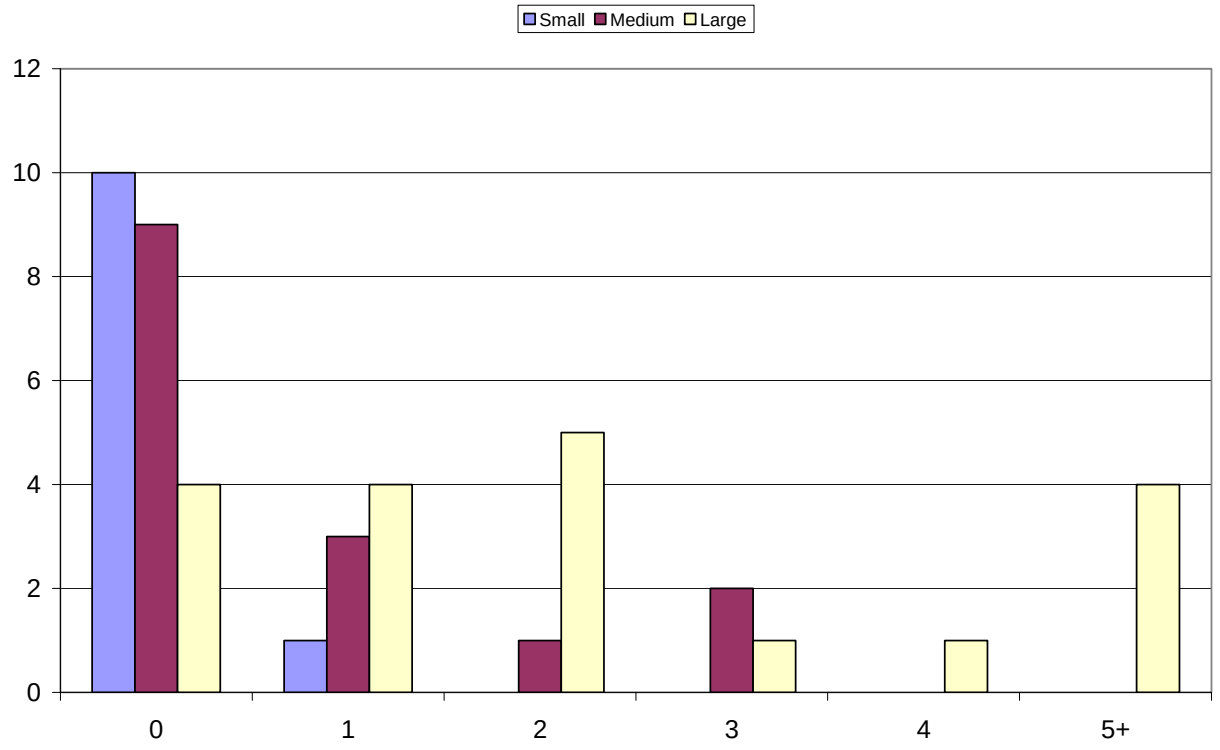
Most agencies (76 percent) do not provide basic scheduling training to other individuals in their agency. Almost half of small and large agencies do provide training to interested persons, most commonly operations staff. Given the fact that the majority of newer schedulers have never experienced manual scheduling, transit operators will increasingly be scheduling with “computer technicians” not well grounded in the underlying basics of scheduling or transit operations.

Years ago, a typical career path for schedulers would be bus operator to supervisor to junior scheduler to senior scheduler. Almost half of responding agencies report that there is no specific career path for schedulers. A career path was more likely to be reported with increasing agency size. While several agencies continue to draw entry-level personnel from the operations ranks, this does not appear to be as common as in the past.

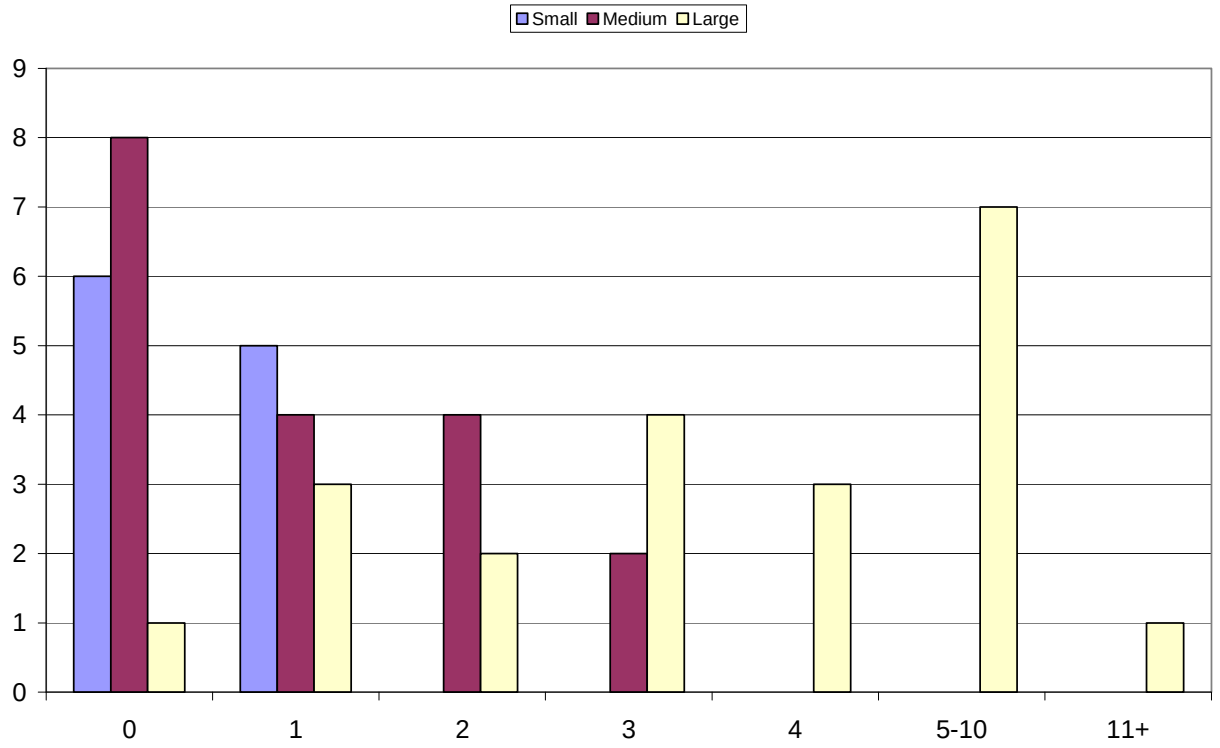
Many transit agencies of all sizes are experiencing an ongoing loss of expertise in scheduling due to retirements. While approximately half of agencies surveyed have not had any schedulers leave in the last five years, 70 percent are expecting at least one retirement in the next five years. Eight large agencies will be losing at least five people each in the upcoming years. Only half have plans in place to handle the number of retirements through recruitment and/or training strategies.

Copyright National Academy of Sciences. All rights reserved.

Q38. How many scheduling department employees have retired within the past five years?



Q39. How many are eligible for retirement within the next five years?



Copyright National Academy of Sciences. All rights reserved.

The onset of sophisticated computerized scheduling tools has increased the training burden, for now there is a need for both basic scheduling training and for application-specific training. Among respondents, training opportunities tend to be focused on computerized scheduling software, conferences, and outside courses, with some in-house training. Agencies reported that the greatest need for training and professional development was for basic scheduling training, with over 60 percent of small agencies stating that basic training is needed. Other areas where training and development are needed include are software training and training in the use of new technologies. Agencies placed a low emphasis on the requirement for application training, which indicates the greater need is for scheduling skills and not application skills.

46. What do you see as the areas of greatest need for training and professional development among scheduling personnel at your agency?

	Small	Medium	Large	Total	%
Basic scheduling training	5	4	6	15	35%
Downstream systems interconnectivity	1		1	2	5%
Interpersonal training			1	1	2%
Knowledge of specific agency	1		2	3	7%
Labor issues training			1	1	2%
Maintaining skill outside of scheduling			1	1	2%
Outside conferences			1	1	2%
Peer studies		3	1	4	9%
Pre-employment screening			1	1	2%
Recruiting			1	1	2%
Refresher training		1	2	3	7%
Schedule development			2	2	5%
Scheduling meal breaks		1		1	2%
Software training		4	3	7	16%
Using new technology - GIS, APC, AVL, etc	1	3	4	8	19%
	8	16	27	43	

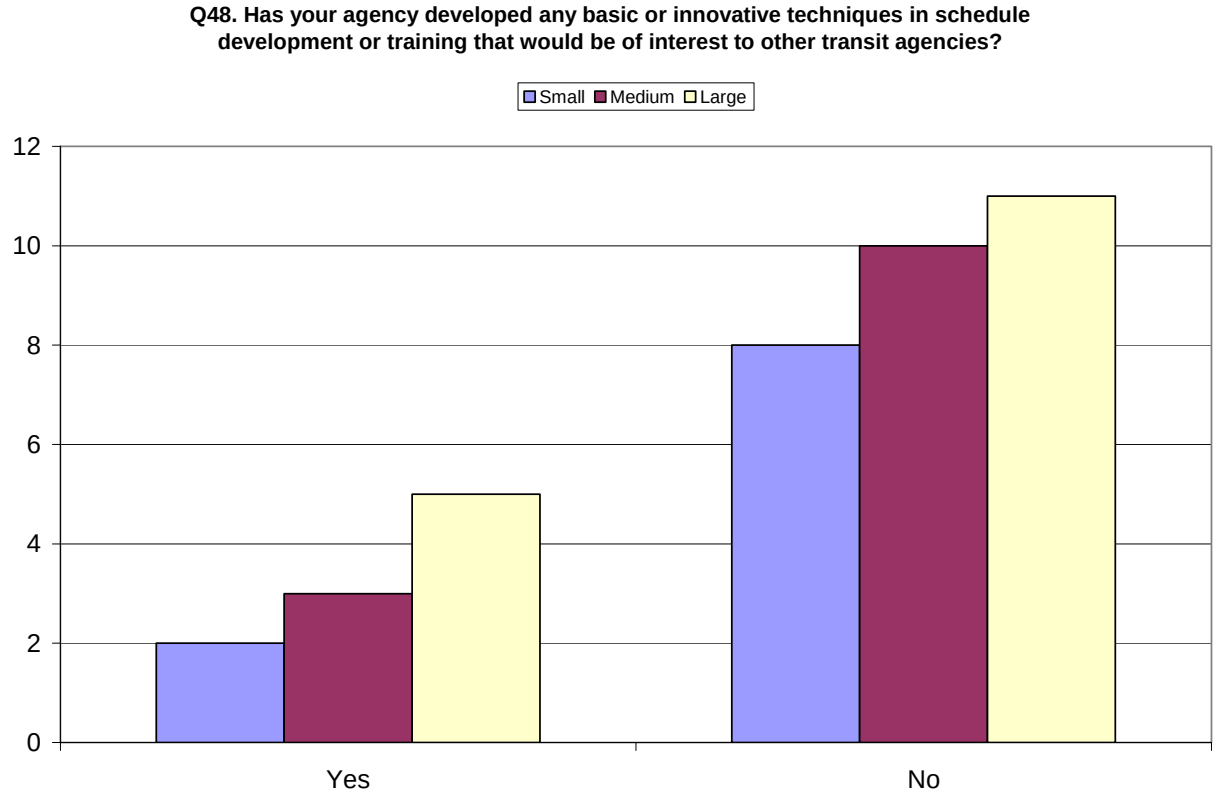
Copyright National Academy of Sciences. All rights reserved.

Despite the perceived need for additional training, over 85 percent of respondents report their scheduling staff proficiency as “excellent” or “good”. A wide variety of criteria was reported to measure schedulers’ performance. The most common criteria are accuracy, cost effectiveness of schedules, ability to complete tasks, and on-time performance.

49. What are the major criteria in measuring the performance of schedulers?					
	Small	Medium	Large	Total	%
Cost effectiveness	3	4	3	10	21%
Schedule accuracy		3	7	10	21%
Completing tasks		2	7	9	19%
On-time performance	5	2	2	9	19%
Schedule efficiency - General	4	2	1	7	15%
Pay/platform	1	2	3	6	13%
Customer feedback	2	2	1	5	10%
% of errors		2	2	4	8%
Recovery/running time			3	3	6%
Driver feedback	1	1		2	4%
Operators added/saved			2	2	4%
Problem solving		1	1	2	4%
Software proficiency		1	1	2	4%
Vehicle hours			2	2	4%
Workload balance		1	1	2	4%
Attention to detail			1	1	2%
Average vehicle speed			1	1	2%
Distance/running time			1	1	2%
Driving time duration			1	1	2%
Efficient use of vehicles			1	1	2%
Initiative			1	1	2%
Interpersonal skills		1		1	2%
Leadership			1	1	2%
Manual runcutting skill			1	1	2%
Organization			1	1	2%
Staff feedback			1	1	2%
				48	

Copyright National Academy of Sciences. All rights reserved.

Only about one-quarter of all agencies reported innovative techniques in schedule development and training. Responses are shown below.



B.10 Rail Scheduling

An early survey question asked about mode-specific scheduling practices and constraints. The most common rail-related response related to dropbacks for either crews or operators. Four agencies cited dropbacks as an important mode-specific practice on either light rail or heavy rail. Other rail-related responses included:

- Almost no running time breaks in light rail (LRT) schedules
- Heavy rail crews have different schedules based on job classification
- Agency pays in-between travel on LRT but not on bus
- LRT has only 8-hour runs (although contract allows 10-hour runs) and all employees are full-time
- Rail capacity constraints
- Vehicle capacity at terminal stations
- Adding and cutting cars on trains
- Analysis of ideal yard assignments, balancing between two yards
- Developing crew blocks from train blocks and cutting the former to handle dropbacks
- Different labor agreements from bus

Copyright National Academy of Sciences. All rights reserved.

Agencies were asked about what scheduling issues specific to light rail they would like to have addressed. Track conflicts led the list, followed by operator drop-backs and multiple car train scheduling.

Q194. Are there any issues related specifically to scheduling light rail service at your agency that should be considered in this study?					
	Small	Medium	Large	Total	%
Track Conflicts			5	5	63%
Operator Scheduling Drop Backs	1		2	3	38%
Multiple car train scheduling	1		1	2	25%
Runcutting			1	1	13%
Yard Duty			1	1	13%
Software training			1	1	13%
				8	

This study is oriented toward bus and light rail scheduling, but the survey included a question about scheduling issues specific to heavy rail. Responses were similar to those of the light rail question, with heavy rail agencies citing operator drop-backs, single track scheduling conflicts, complex scheduling with operators operating multiple trains, runcutting, and yard duty.

Copyright National Academy of Sciences. All rights reserved.

B.11 Toward the Scheduling Manual

Two questions on the survey were designed to elicit agency responses indicating key scheduling issues and needs that the new scheduling manual could address. The first question asked about current issues at the agency that this study could help to answer. Issues receiving multiple responses included computerized scheduling, recovery/layover guidelines, recruitment and training of schedulers, and scheduling practices at other agencies. Respondents mentioned a wide variety of issues that included basic, intermediate, and advanced topics.

23. Are there any current issues regarding scheduling at your agency that this study could help to answer?					
	Small	Medium	Large	Total	%
Computerized scheduling: pros and cons			3	3	14%
Computerized scheduling: general		2		2	9%
Recovery/Layover Guidelines		1	1	2	9%
Schedulers: hiring, recruiting, training, replacing			2	2	9%
Scheduling techniques at other agencies			2	2	9%
Adjusting schedules annually based on ridership and congestion		1		1	5%
Attendance policy		1		1	5%
Bus stop placement			1	1	5%
Computerized scheduling: training		1		1	5%
Contract rules at other agencies		1		1	5%
Creating 4 day/10 hour schedules			1	1	5%
Downstream data management			1	1	5%
Drop back scheduling			1	1	5%
Handling bus shortages			1	1	5%
Interlining	1			1	5%
Managing school services		1		1	5%
Meal break scheduling	1			1	5%
Overtime vs. Additional operators: pros and cons			1	1	5%
Rostering techniques		1		1	5%
Runcutting in multi-depot rail systems			1	1	5%
Training at all levels	1			1	5%
Use of Part Time Drivers			1	1	5%
Using AVL/APC data		1		1	5%
Using taxis for relief			1	1	5%
	3	10	17	22	100%

Copyright National Academy of Sciences. All rights reserved.

The second question asked about the agency's greatest needs that should be addressed in the scheduling manual. Interestingly, this question was answered by almost twice as many agencies. The most frequently mentioned needs included training for new staff, computerized scheduling, basic scheduling concepts, and cost efficiency. As with the previous question, respondents mentioned a wide variety of issues that included basic, intermediate, and advanced topics.

24. What are your agency's greatest needs regarding scheduling that this scheduling manual should address?					
	Small	Medium	Large	Total	%
Training for new staff	2	3	4	9	23%
Computerized scheduling	1	4	1	6	15%
Basic scheduling - headway determination, runcutting, rostering, interlining		1	4	5	13%
Cost efficiency	2	1	1	4	10%
Case studies of operators		1	1	2	5%
Exception scheduling		2		2	5%
Running time analysis		1	1	2	5%
Scheduling meal breaks	1	1		2	5%
Using AVL, APC, GIS		1	1	2	5%
Behavioral problems with drivers - attitude affecting schedule			1	1	3%
Comparing scheduled and actual work		1		1	3%
Complex schedule visualization			1	1	3%
Consistent transit nomenclature	1			1	3%
Contact list of operators			1	1	3%
Downstream data maintenance		1		1	3%
Driver retention		1		1	3%
Drop back scheduling			1	1	3%
Evaluating runcut and blocking efficiency		1		1	3%
How service planning relates to scheduling			1	1	3%
Increasing service transition	1			1	3%
Industry standards		1		1	3%
Layover/Recovery time incorporation and calculation		1		1	3%
Scheduling connections to other modes		1		1	3%
Splitting shifts	1			1	3%
Staff size by agency size		1		1	3%
Text book			1	1	3%
				40	

B.12 Agency Survey

A copy of the agency survey is provided on the following pages.

Copyright National Academy of Sciences. All rights reserved.

Transit Scheduling Survey Draft - Transit Agencies

TCRP Scheduling Manual - Transit System Survey

RESPONDENT INFORMATION

1	Date:	
2	Name and Title of Respondent:	
3	Respondent Telephone Number:	
4	Respondent e-mail address:	
5	Is your agency willing to participate in a more detailed case study later in this project?	Yes/no only

TRANSIT SYSTEM INFORMATION

6	Agency Name:			
7	City			
8	State			
9	***Transit System Size***	**Bus**	**LRT**	**Heavy Rail**
	Weekday Peak Vehicles			
	Weekday Off Peak Vehicles			
	Saturday Peak Vehicles			
	Sunday Peak Vehicles			
	Total full-time operators (drivers)			
	Total part-time operators (drivers)			
	# Bus garages (including those related to contracted services)			
	# Bus garages for contracted services			
	Smallest garage/yard size-total # operators			
	Largest garage/yard size -total # operators			
	Smallest garage/yard size-# vehicles			
	Largest garage/yard size-# vehicles			

GENERAL SCHEDULING QUESTIONS

10 What mode-specific scheduling practices and/or constraints are applied at your agency?

11 Please rank from 1 (most important) to 6 (least important) the following as driving forces causing the need to update schedules, blocks, and runs.

Service changes	
Labor agreement changes	
Regular bid requirements	
Budget issues	
Ridership growth	
Other	

If other, please describe below

Copyright National Academy of Sciences. All rights reserved.

12 Does your agency use any innovative or alternative approaches to scheduling that may be of interest to other systems?

13 What is the relationship between fixed-route and paratransit scheduling?

14 Typically, what percentage of your agency's routes have service changes in any given year?

15 How long does the schedule creation process typically take, from concept through to implementation?

16 Is union review and approval required before new schedules can be implemented? Yes/no only

17 Are there any unusually restrictive rules or practices at your agency?

18 If bids/service change dates are fixed, what is the process for making ad-hoc scheduling changes between picks?

19 Does "exception" scheduling (i.e., preparation of temporary schedules to account for special events, street closures, track work, or other disruptive events) account for a significant ongoing portion of the scheduling department's workload? Yes/no only

20 If yes, what percentage of the scheduling department's time does it typically account for?

21 How does your agency address scheduling for these occasions?

22 Which parts of the labor agreement or scheduling practices have the greatest impact on overall scheduling efficiencies? Put another way, what would you change if you could?

23 Are there any current issues re scheduling at your agency that this study could help to answer?

Copyright National Academy of Sciences. All rights reserved.

24 What are your agency's greatest needs re scheduling that this scheduling manual should address?

SCHEDULING ORGANIZATION

25	Are your agency's schedulers represented by a union?		Yes/no only
26	If Yes,		
	Same union as bus operators		"X" only one
	Different union from that of the bus operators		
27	Where does the scheduling department fit within the organization? (e.g. operations, planning, marketing, regional). Please provide organization charts showing where the scheduling department fits and how it is organized, if these are available, to the email address at the end of this questionnaire.		
28	What is the size of the scheduling department (full time equivalents)?		
29	In your opinion, is the scheduling department adequately staffed to meet its obligations?		Yes/no only
30	If not, what would be the appropriate size (in FTEs) of the scheduling department?		
31	Is your scheduling function, or any part of it, outsourced?		Yes/no only
32	If yes, what percentage is typically performed by the contractor?		

33 How are manpower requirements for the scheduling department determined?

34 How are schedulers recruited? What are the minimum requirements for schedulers at your agency? From what backgrounds do your agency's schedulers come? Have they worked in transit operations? Have they worked in planning? Do they have college degrees, and in what subjects?

35 How does your staff learn to become schedule makers? Is there an apprenticeship, mentoring or in house training program?

36 Please describe the career path for schedulers in your agency.

Copyright National Academy of Sciences. All rights reserved.

37 Do schedulers work across all aspects of scheduling, or do they work within specific tasks (e.g. runcutting only), or within geographic regions (e.g. one division only)

38 How many scheduling department employees have retired within the past five years?

39 How many are eligible for retirement within the next five years?

40 Is there a plan to address future personnel needs? Yes/no only

41 If so, please describe below.

42 If we define "core" scheduling tasks as schedule writing, blocking, run cutting, and rostering, are any of the following non-core scheduling tasks being undertaken within the scheduling department to meet the requirements of interfacing with other departments?

- Stop management
- AVL data
- APC data
- Other (please describe)

"X" all that apply

43 Describe any downstream data requirements for scheduling outputs at your agency.

- Stop inventory
- AVL data
- APC data
- GIS
- Telephone information
- Public timetables
- Itinerary planning
- Bus stop schedules
- Other (please describe)

"X" all that apply

44 Describe the breakdown of scheduling staff time allocation (in percentage terms):

- Schedule writing & blocking
- Run cutting
- Period rostering
- Run times & ridership data analysis
- Data management for downstream systems
- Other (please describe)

45 Please describe any in-house training opportunities and training courses or conferences that schedule department personnel have attended in the past two years.

46 What do you see as the areas of greatest need for training and professional development among scheduling department personnel at your agency?

Copyright National Academy of Sciences. All rights reserved.

47 Is basic schedules training provided for anyone not directly involved in scheduling within your agency? If so, who provides this training, and what does it consist of?

48 Has your agency developed any basic or innovative techniques in schedule development or training that would be of interest to other transit agencies? Please describe below.

49 What are the major criteria in measuring the performance of schedulers?

50 How would you rate the proficiency of your schedule department staff overall?

- Excellent
- Good
- Average
- Below Average

"X" only one option

51 What percentage of scheduling tasks are actually implemented (compared to tasks undertaken for costing or evaluation purposes only)?

SCHEDULE WRITING

52 How often are schedules adjusted on a typical route (aside from running time changes)? For the purposes of this question, an adjustment is anything more than moving trips by a minute or two.

- Quarterly
- Seasonally (e.g., school year/summer)
- Annually
- Every two years
- As needed
- Have not been adjusted on any route in the past two years

"X" all that apply

53 Please provide an overview of how schedules are developed at your agency.

54 How are headways/frequencies determined? *(Check all that apply)*

- Application of service guidelines

Copyright National Academy of Sciences. All rights reserved.

Policy headways
Ad hoc, depending on the route and its history
Budgetary considerations
Other (please describe)

"X" all that apply

55 Where average or peak loads are used, how is the load factor determined?

56 Does your agency have documented service standards? Yes/no only

57 Does your agency operate more than one type of vehicle (e.g., different size) on a route within a given time period? Yes/no only

58 Please describe any other factors that influence headway and schedule development

59 Are clockface headways considered important at your agency? Yes/no only

60 If yes, at what frequency level are clockface headways considered unnecessary?

61 Are all times at timepoints published, or are only general headways published?
All times at timepoints
General headways
Depends on frequency of service

"X" only one option

62 Does your agency produce and publish stop-specific timetables for each stop in the system (as opposed to at timepoints only)? Yes/no only

63 If yes, please describe how your agency calculates times between timepoints

64 Does your agency operate any express, limited stop or skip stop services? Yes/no only

65 If yes, please describe, and explain how schedules are generated, and any differences from how other schedules are written.

66 Does your agency operate timed transfer locations? Yes/no only (If no, skip to Question 71)

67 Does your agency operate multi-modal timed transfers or planned multi modal coordinated schedules? Yes/no only

68 What transfer window is allowed for where scheduled transfers are defined? Please give a specific value or, if appropriate, a range, and describe any variations below (e.g., by mode, by location, by time of day, etc.).

69 Approximately what percentage of routes have at least one timed transfer?

70 How many timed transfer locations are in your agency's transit network?

Copyright National Academy of Sciences. All rights reserved.

71	Does your agency operate school-day only trips?		Yes/no only
72	If yes, are schedules, blocks and runs adjusted for non school days?		Yes/no only
73	Where multiple routes operate over a common corridor, are those routes intertimed?		Yes/no only
74	Are schedules written to ensure they can link effectively into blocks?		Yes/no only

RUNNING TIMES/LAYOVERS

75	How often is running time data collected for a typical route?		
76	What sources of running time data are available? (*Check all that apply)*		
	Manual checks		"X" all that apply
	AVL data		
	APC data		
	Other (please describe)		
77	Are single or multi-day data used?		
	Single day		"X" only one option
	Two or three days		
	More than three days		
78	How often are running times adjusted?		
79	Describe, in summary form, your agency's approach to calculating appropriate running times (e.g., use of averages, a certain percentile, professional judgment, negotiation with unions).		
80	Do any system policies (folding strollers, all seated passengers, or others) affect dwell time?		Yes/no only
81	If so, please elaborate.		
82	Does vehicle type (e.g., double-deckers, low-floor buses) affect dwell time at your agency?		Yes/no only
83	If so, please elaborate.		
84	Do operators have the opportunity to participate in the process used to determine running times?		Yes/no only
85	Does your agency use different running times at different times of the day, and on different days of the week?		Yes/no only
86	Minimum layover prescribed by labor contract rules (describe below)		
87	How does your agency address minimum layover requirements?		

Copyright National Academy of Sciences. All rights reserved.

88 How would your agency address minimum layovers if no labor agreement restrictions were in place?

89 Does your agency provide mid-route layover time on any of your routes (e.g., to ensure timed transfers at certain locations)? Yes/no only

90 If yes, does this count toward minimum layover time for the route? Yes/no only

91 Does your agency distinguish between layover time and recovery time? Yes/no only

92 Do longer routes show trends towards less reliability on running time at your agency? If yes, by what percentage?

93 Has the advent of automated data improved the overall reliability of your services (through improved ability to update running times)? Please explain how.

94 In summary, How does your agency manage running time/layover evaluation?

BLOCKING

95 Is blocking undertaken on a route, garage, division, or systemwide level?
Route level
Garage level
Division/area/region level
Systemwide
Other (please describe)
"X" all that apply

96 Are trips and blocks interlined? Yes/no only

97 If yes, what % of trips are interlined?

98 Is there any evidence of negative reliability impacts of interlining at your agency? Please describe.

99 Does your agency undertake "optimized" systemwide blocking, where you seek an optimal solution across the entire system while considering all aspects of service and all constraints? Yes/no only

100 If yes, please describe the frequency and nature of this optimization.

Copyright National Academy of Sciences. All rights reserved.

101 Are there any labor contract limitations/constraints on the blocking process? Yes/no only

102 If yes, please describe.

103 What parameters are used to define if a blocking solution is efficient (e.g. peak vehicles, % layover etc.)? Please describe.

104 Are historical comparisons of blocking solutions kept? Yes/no only

For Questions 105-107, if you calculate overall weekly or annual percentages, repor the overall number; otherwise, report weekday, Saturday and Sunday separately

		Overall	Weekday	Saturday	Sunday
105	What is layover as % of platform time at your agency?				
106	What is layover as % of in service time at your agency?				
107	What are deadhead plus garage pull-in and pull-out times as % of platform time at your agency?				

108 For multi-garage agencies, when was the last time you undertook a garage optimization study?

109 When creating blocks, are the impacts on runs (e.g. block lengths) taken into account? Yes/no only

110 Do you have vehicle type and/or modal constraints to consider when blocking? Yes/no only

111 If yes, please describe

RUN CUTTING

112 Please estimate your agency's pay to platform ratio from the most recent runcut without including extraboard in the total pay hours.

Weekday
Saturday
Sunday

113 At what level does your agency undertake run cutting - route level, garage level, division level, or systemwide?

Route level
Garage level
Division/area/region level
Systemwide
Other (please describe)

"X" all that apply

114 Please summarize key elements/limitations of your labor agreement

Copyright National Academy of Sciences. All rights reserved.

115 What constitutes "overtime" for operators?
Over 8 hours a day (10 hours for a four-day week)
Over 40 hours a week
Either of the above
Other (please describe below)

"X" only one option

116 How does your agency view the trade off between additional operators compared to the cost of additional overtime? Have any detailed analysis been undertaken (if so, what were the results)? Does your agency avoid overtime at all costs?

117 What parameters are used to define if a run cut is efficient (e.g. total operators, pay/plat), or to compare options? Please describe.

118 Are historical comparisons of run cut solutions kept? Yes/no only

119 Does your agency have guaranteed minimum time for full-time operators? Yes/no only

120 Is guarantee/make-up time calculated daily or weekly?
Daily
Weekly
Both

"X" all that apply

121 Does your agency require "make-up" time to fill a run that would otherwise be less than 8 (5-day week) or 10 (4-day week) hours per day? Yes/no only

122 Does your agency require "make-up" time to fill weekly assignments that would otherwise be less than 40 hours per week? Yes/no only

123 Does your agency schedule paid travel time or relief allowances? Yes/no only

124 Are there contract limitations on the number or percentage of part-time operators? Yes/no only

125 If yes,
Upper limit
Lower limit

126 Are there upper and lower limits for weekly hours worked for part time operators? Yes/no only

127 If yes,
Upper limit
Lower limit

128 Are there other limitations on the use of part-time operators? Yes/no only

129 If yes, please describe.

130 Does your agency have guaranteed minimum time for part-time runs? Yes/no only

131 If yes, please describe

Copyright National Academy of Sciences. All rights reserved.

132 Please describe below how operators get to/from relief points. This could include several methods.

133 Describe how your agency schedules operator meal breaks and operator rest breaks.

134 How are operator breaks determined?

- Labor Agreement
- Law
- Preference/operating practice

"X" all that apply

135 Please describe the spread penalty at your agency.

136 Are report and turn-in time included in the spread calculation? Yes/no only

137 Are there any limitations on multi-piece runs? Yes/no only

138 If yes, please describe.

139 Please describe any constraints that pose the greatest restriction or impacts on runcut development.

PERIOD ROSTERING

140 Please provide a brief overview of how period rosters are created and administered.

141 How is your agency's extraboard/relief component sized? Is this a contract requirement or an agency formula? Please describe below.

Copyright National Academy of Sciences. All rights reserved.

142 Are picks rostered or is a cafeteria style system used? Please describe in greater detail below.

Rostered
Cafeteria
Other (please describe)

"X" one only

143 Do drivers pick their days off, or are these assigned within each line of work?

Drivers pick
Assigned by scheduling staff into period (i.e. weekly, monthly) lines of work
Other

"X" one only

144 Do drivers work on the same line of work from week to week, or do they rotate through the runs over a period of time?

Same from week to week
Rotate
Other (please describe)

"X" one only

145 Are consecutive days off required for full-time work pieces?

Yes/no only

146 Can work pieces include a combination of extraboard/relief and regular run assignments?

Yes/no only

147 Do part-time operators pick work or are they assigned work?

Pick their work
Assigned by roster
Assigned by operations staff

"X" all that apply

148 Does your system allow 4-day work weeks for operators?

Yes/no only

149 If yes, what percentage of work weeks are 4/10, and what percentage are 5/8?

4/10 percentage
5/8 percentage
Other percentage

150 What is your agency's view of the optimum mix of 4/10, 5/8 and part time operators. Has a detailed analysis been conducted? Please describe below.

151 Is all work picked, or is some left for extraboard/relief to cover?

All picked/covered
Some left uncovered

"X" one only

152 If work is left uncovered, what % is typically left uncovered?

153 How are vacated runs primarily filled?

Picked through seniority
Line pick
Extraboard
Other (please describe)

"X" one only

154 Please describe how runs are posted and selected.

155 Please describe any constraints that pose the greatest restriction on roster development.

Copyright National Academy of Sciences. All rights reserved.

COMPUTERIZED SCHEDULING

156 Does your agency use a computerized scheduling package? Yes/no only (If no, skip to Question 193)

157 If yes, what software package is used?

158 When was it originally procured?

159 Which modules were purchased?

160 When did your agency last upgrade?

161 Describe updates, including modules added

162 How long (from signed contract) did the original implementation project take?

163 Please provide the approximate cost for:
- Original software license & training
- Software implementation
- Software upgrades
- Software maintenance (annual cost)

164 Please indicate which parts of the scheduling process have been automated - by mode, where applicable

	Bus	LRT	Heavy Rail
Planning routes			
Developing running times			
Building trip tables			
Blocking			
Runcutting			
Rostering			
Managing the sign-up			
Extraboard sizing			
Part-time operator assignment			
Traffic data collection			
Daily crew assignment/absentee management			
Daily dispatching			

X all that apply

165 Has your agency calculated savings directly attributable to implementation of computerized scheduling software (formally or informally)? Yes/no only. If yes, please answer next question.

166 If yes, what were the savings?
- $ terms
- % of operating costs

167 Is the package used by other staff in the organization (e.g. planning staff, operations staff)? Yes/no only. If yes, please answer next two question.

168 If so, by whom?

169 If so, how is the package used?
- Longer term planning
- Daily operations/dispatch
- Absence management
- Mapping

X all that apply

Copyright National Academy of Sciences. All rights reserved.

Other (please specify)

170 To what extent are the solutions produced by your computerized system utilized (i.e. are they implemented directly, or do they require manual fine-tuning - and if so, to what extent)?

171 Has your agency assessed other benefits and/or efficiency impacts resulting from implementation of computerized scheduling software? If so, please describe below.

Yes/no options

172 Has the size of your agency's scheduling department changed as a direct result of implementation of computerized scheduling software?

Yes/no only. If yes, please answer next question.

173 If yes, how has it changed?

Increased (by how many positions)

Decreased (by how many positions)

Only fill one

174 What percentage of the current scheduling department staff did manual scheduling (at your agency or another agency) prior to the implementation of computerized scheduling software?

175 Has the time it takes your agency to produce and implement schedules changed as a direct result of implementation of computerized scheduling software?

Yes/no only. If yes, please answer next question.

176 If yes, how has it changed?

Increased (by how long)

Decreased (by how long)

X one option only

177 Has the implementation of computerized scheduling software increased either expectations of turnaround time or the volume of "what-if" tasks?

Yes/no options

178 Overall, have the estimated benefits of implementing computerized scheduling been realized?

Yes, fully realized

Yes, partially realized (describe issues in Q. 148)

No (describe issues in Q. 148)

X one option only

179 Describe any related issues.

180 Does your agency's computerized scheduling software interface with other agency data systems?

Yes/no only

181 If yes, which systems (payroll, dispatch, AVL etc)

182 Has your agency switched within the past two years from one scheduling package to another?

Yes/no only. If yes, please answer questions 183-189

183 What was the original package?

Copyright National Academy of Sciences. All rights reserved.

184 What is the new package?

185 When was the new system purchased?

186 When was the original system purchased?

187 What were the main reasons for changing systems?

188 Overall, have the estimated benefits of changing systems been realized? Yes/No only

189 Describe any related issues.

190 Does the integration of your current computerized scheduling software with other agency functions preclude consideration of a change in scheduling packages? If yes, please elaborate below. Yes/No only

191 If yes, please elaborate below.

192 If not using computerized scheduling software, what general software tool does your agency *primarily* use to build schedules?

- Spreadsheet
- Database
- Word processor
- Other (please describe)

"X" one option only

193 If not using computerized scheduling software, please describe how schedules, blocks and runs are built

RAIL SCHEDULING

194 Are there any issues related specifically to scheduling light rail service at your agency that should be considered in this study?

195 Are there any issues related specifically to scheduling heavy rail service at your agency that should be considered in this study

Copyright National Academy of Sciences. All rights reserved.

Transit Cooperative Research Program Project A-29
Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

Appendix C
Vendor Survey Results

C.1 Introduction and Methodology

The Vendor Survey, undertaken as a Phase I task of TCRP Project A-29, was developed as a tool for obtaining information from vendors of computerized scheduling software packages regarding clientele, software features, training needs, and trends in the transit industry. The survey, provided in the final section, included 31 questions.

The project team received only four responses from vendors. One vendor's product was designed primarily for paratransit services. Another vendor answered most questions "cannot disclose" or "varies by agency." Thus, the results are far from statistically significant. The diligent respondents did offer several interesting observations from the vendors' perspective, and these are reported in the following section.

C.2 Vendor Observations

- **Purchasing patterns**. Most agencies buy the basic software package. Approximately half will then upgrade to other modules.

- **Utilization**. There is a strong tendency to revert to manual methods. Optimized blocking and runcutting tools are underutilized, along with tools to generate statistics and reports.

- **Research**. Roughly 1/3 of the vendors' budgets go to research and development. Forty percent of recent software development has been directly related to traditional scheduling elements (i.e., schedule writing, blocking, crew scheduling, and period rostering). The most critical R&D trends are:

    - User interface issues;
    - Multimodal applications;
    - Real-time transfer of data among different systems (scheduling, AVL, trip planning, payroll, timekeeping, human resources);
    - Expanded capabilities vs. fixed staff.

- **Training** issues include: lack of familiarity with computers; availability of personnel for training (the scheduling function continues through any transition); time gap between training and actually using the software; "but that's the way we've always done it."

- **Computer/IT capabilities** of scheduling staff vary widely. Comfort with using a computer and ability to grasp more complex scheduling concepts are keys to success.

- **Major scheduling issues** facing the transit industry, as seen by the vendors, include:

    - Reduced processing time for the production of schedules;

Copyright National Academy of Sciences. All rights reserved.

- Eventual real-time scheduling to take daily variations into account;
- Improved intermodal synchronization;
- Willingness on the part of agencies to reject the status quo in favor of new ideas and approaches;
- Lack of good in-house IT/computer skills.

- **How could computerized scheduling software be better utilized?** "Slack" time for schedulers to play with the application and find better ways to do their daily work is rare because many scheduling departments are minimally staffed. In a perfect world, users would spend more time using the software to test various operational scenarios. Regular training (basic for new personnel and advanced to address more complex issues) would also help agencies maximize the benefits of scheduling software.

- **Post-implementation changes**. The type of work changes in two phases: initially, more time is devoted to the quality of the schedule/ runcut/roster instead of just getting it done. But as more applications are developed, less time is spent tweaking the schedules and more time devoted to downstream requirements. No changes in the size of scheduling departments are observed after implementation.

Copyright National Academy of Sciences. All rights reserved.

C.3 Vendor Survey

I. RESPONDENT INFORMATION

1. Vendor Name:

2. Survey Date:

3. Name and Title of Respondent:

4. Respondent Telephone Number:

5. Respondent e-mail address:

6. Software name:

7. # employees:

8. Annual sales:

9. Year company was established:

II. CLIENTELE

10. Number of scheduling software program installations:

    a. Within the United States
    b. Worldwide:

11. Number of installations with peak vehicle count between:

    a. 1-50:
    b. 51-100:
    c. 101-250:
    d. 251-500:
    e. Over 500:

12. Modes the system is used for (count clients for each mode):

    a. Bus:
    b. Bus Rapid Transit:
    c. Light Rail/Tram:
    d. Heavy Rail (Metro, subway, etc.):
    e. Commuter Rail:
    f. Intercity Rail:

Copyright National Academy of Sciences. All rights reserved.

III. FEATURES

13. Modules offered by the system (check as appropriate):

    a. Schedule writing
    b. Manual blocking
    c. Automated blocking
    d. Manual crew scheduling
    e. Automated crew scheduling
    f. Period rostering
    g. Period rostering with rotations
    h. Crew sign-in and day of operations assignment
    i. Other

14. Non-scheduling modules available? (check as appropriate):

    a. Geographic information system
    b. Run time analysis
    c. Ridership analysis
    d. Census data analysis
    e. Other

15. Please describe (in summary form) the purchasing patterns of transit agencies.

    a. What percentage purchase the bare-bones scheduling package?
    b. What percentage purchase additional modules?
    c. Of these, what percentage purchase the added modules jointly with the basic package, and what percentage purchase the added modules later?

16. Please describe any mode-specific software features of your system.

17. Which software capabilities are typically underutilized by your transit clients? Please describe.

IV. RESEARCH

18. What percentage of your annual expenditures is assigned to research and development?

19. What percentage of recent software development has been directly related to traditional scheduling (i.e., schedule writing, blocking, crew scheduling, and period rostering)?

V. TRAINING

20. What percentage of project budgets is typically committed to training?

21. How much and what types of training are typically undertaken for a system implementation?

22. Does your company do the training itself?

23. What are the most common issues that arise with training transit agency staff?

Copyright National Academy of Sciences. All rights reserved.

24. Please describe your perceptions of the computer/IT capabilities of scheduling staff that you train.

VI. INDUSTRY TRENDS

25. Over the past five years, what percentage of your business has been:

    a. new sales
    b. upgrades to existing customers, including additional modules

26. What do you see as the most critical current research and development trends related to computerized scheduling software?

27. In your company's view, what are the major scheduling issues facing the transit industry?

28. Are you satisfied with how effectively your clients utilize your system?

29. How could your existing software be better utilized by your clients?

30. Have you observed reductions in the size of scheduling departments after the implementation of your software? If so, to what extent?

31. Is there anything specific you would like to see included in the revised industry scheduling manual?

Copyright National Academy of Sciences. All rights reserved

Transit Cooperative Research Program Project A-29
Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

Appendix D
Additional Research Needs

The purpose of this appendix is to identify gaps in knowledge and relevant issues that have emerged since the publication of TCRP 30. A close reading of survey responses, comments and questions from respondents, the team's experience in various scheduling environments throughout the United States and the world, and vendor insights all contribute to the findings noted here. The project team views this task as a means to define scheduling issues that *must* be addressed in the new scheduling manual.

Critical issues needing further attention include:

1. Computerization. Since TCRP 30, the use of computerized scheduling software packages has reached a "critical mass" level. This is the single biggest difference between then and now. The new manual must address issues related to computerized scheduling. A discussion of how to manage the transition from a manual to a computerized system would also be helpful, along with an analysis of the effects of computerization. The intent is not to replicate software training provided by vendors, but to provide a context of what is possible using computerized scheduling packages. Examples might include trip shifting, different specifications of parameters in runcutting and blocking, interpretation of software outputs, and typical "what-if" applications.

2. Basic scheduling skills. One important market for any scheduling manual is the beginning scheduler. The survey results reveal that most training is on-the-job and informal, frequently involving a mentor from whom the rookie scheduler learns. In fact, several agencies that have developed tests or training manuals in-house limit their use, for human resources or other reasons, to screening potential applicants for entry-level scheduling positions. A concise presentation of the "nuts and bolts" of scheduling is essential. Even at computerized agencies, it is not unusual for the scheduler to adjust the results of the computer generated schedules, and so there is a continuing need for scheduling knowledge and skills.

3. Advanced "tricks of the trade." The TCRP 30 project team evaluated the manual prior to publication. Most schedulers reported that, while it was useful for entry-level personnel, it really did not teach them anything new. Yet the survey results indicate a great deal of curiosity regarding how other agencies address issues such as running time, meal breaks, transfer windows, and restrictions related to union rules or past practices. One impact of the trend toward computerization is that schedulers are freed from many time-consuming manual tasks and can devote more time to advanced scheduling issues. For agencies operating out of multiple depots, computerization lends itself to "what-if" analyses regarding the effect of split depot operations on peak vehicle requirements. Computerization also allows for the production of time-space diagrams that can help schedulers visualize bus bunching, headways, and layovers. There may also be a role for statistical process control in calculating running times.

Copyright National Academy of Sciences. All rights reserved.

4. Terminology. Despite our best efforts, some respondents were confused by certain terms. In addition, agencies often use different terminology for scheduling-related functions. A good glossary is a must in the new manual. A glossary was prepared for TCRP 30, but was not included in the final publication.

5. Downstream requirements and how to handle. Because of its impacts on system cost and efficiency, scheduling was never truly an isolated function. However, as new technologies allow or require greater data integration, there are increasing downstream requirements for scheduling output and greater demands for interaction with other departments. These requirements can change the nature of the scheduler's job. Examples of the effects of integration and strategies for addressing downstream requirements would be particularly beneficial.

6. Breaks (lunch and other). As noted earlier, several respondents expressed interest in how other agencies schedule breaks for their drivers. Drop-backs are universally used in rail scheduling, but are not in widespread usage at bus agencies. Some bus schedulers wanted to know more about how drop-backs worked.

7. Training methods. A concise, organized, and well-written scheduling manual is viewed as a welcome addition at most agencies. In this multimedia age, however, alternate means of expressing scheduling concepts must be considered. TriMet used TCRP 30 as the foundation for an interactive training program developed by computer programming interns. Without getting into the question of the best way for people to learn scheduling, we should be aware of the potential of different learning paradigms. A few respondents noted that people interested in puzzles (crosswords, sudoku, or others) often prove to be the best candidates for entry-level scheduling positions. An interactive manual oriented toward puzzle-solving is an intriguing concept as a teaching tool.

8. Cross-agency communication among schedulers. The high level of interest in other agencies' approaches to common scheduling issues suggests that the manual should wherever possible make use of examples drawn from actual practice. These examples would move the scheduler beyond a "we've always done it this way" approach, and would also help to illuminate cases in which there is not a single best answer.

The scheduling manual has incorporated these needs, many of them as discussion topics in advanced sections of the manual. Computerization is addressed throughout the manual, and the manual has been structured to take a beginner through all the steps he/she needs to become a proficient scheduler. The margins of the manual include a running glossary and "tricks of the trade" in the form of tips. Nevertheless, there are still research needs to be met as scheduling evolves. Fruitful areas of additional inquiry include establishing running times, use of headway-based schedules, overtime optimization, rotary rostering (rare in the United States), and extraboard management. The scheduling manual reflects the state of the art in 2009 and offers a beginning point in addressing these areas. As technology evolves and additional and more reliable data become available, subsequent research activities will offer clear benefits to schedulers and to the transit industry as a whole.

Copyright National Academy of Sciences. All rights reserved.

Transit Cooperative Research Program Project A-29
Controlling System Costs: Basic and Advanced Scheduling Manuals and Contemporary Issues in Transit Scheduling

Appendix E
Case Studies

E.1 Introduction

This appendix summarizes findings of the case studies. The project team proposed twelve case studies, after final approval by the project panel, to address a range of scheduling issues and cover a wide variety of transit systems. The systems proposed as case study sites were selected on the basis of a range of scheduling factors. Each case study is proposed in order to represent a particular set of scheduling issues.

Table E.1 lists the case study sites.

Table E.1
Case Study Agencies

Agency	City	State
1. Los Angeles MTA	Los Angeles	CA
2. San Diego Trolley, Inc.	San Diego	CA
3. Santa Monica's Big Blue Bus	Santa Monica	CA
4. Regional Transportation District	Denver	CO
5. StarMetro	Tallahassee	FL
6. Montgomery County Ride On	Rockville	MD
7. Capital Area Transportation Authority	Lansing	MI
8. Metro (Bi-State Development Agency)	St. Louis	MO
9. Capital District Transportation Authority	Albany	NY
10. MTA New York City Transit	New York	NY
11. Toronto Transit Commission	Toronto	Ontario
12. TriMet	Portland	OR

E.2 Case Study Agency Selection Evaluation Framework

The project team reviewed survey outputs in detail in order to choose agencies for further evaluation that would best contribute to meeting the revised scheduling manual objectives. The agencies were categorized according to a range of criteria including:

- Geography
- Size
- Computerized/manual
- If computerized, which software package
- Extent of data & non-core scheduling tasks
- Scheduling department size & location within organization
- Interesting aspects of scheduling approaches, rules, constraints or issues

Copyright National Academy of Sciences. All rights reserved.

For each of these criteria, the objective was to select a representative cross-section across all factors, cross-tabbed against as many of these factors as possible. These include, for example, a range of geographic locales, and an even spread of computerized systems by size (e.g. even split between Hastus & Trapeze across system size). The proposed case study agencies ensure that these objectives are met.

Table E.2 presents the proposed case study systems along with their respective criteria.

Table E.2
Proposed Case Studies within the Evaluation Framework

Agency	City	State	Region	Peak Buses	Size	System	Interfaces & Non Core tasks	Sched. Dept. Size	Buses per Sched-uler	Sched. Dept Location
Los Angeles MTA	Los Angeles	CA	West	2,179	Large	HASTUS	High	23	95	Operations
San Diego Trolley, Inc.	San Diego	CA	West	196	Medium	HASTUS	Medium	2.5	78	Planning
Santa Monica's Big Blue Bus	Santa Monica	CA	West	149	Medium	Trapeze	Medium	1	149	Operations
Denver RTD	Denver	CO	Central	868	Large	Trapeze	High	19	46	Customer Service
StarMetro	Tallahassee	FL	South	52	Small	Manual	Low	2	26	Operations
Montgomery County Ride On	Rockville	MD	East	297	Medium	Manual	Low	6	50	Operations
Capital Area Transportation Authority	Lansing	MI	North	75	Small	Trapeze	Medium	1	75	Planning
Metro (Bi-State Development Agency)	St. Louis	MO	Central	322	Large	Trapeze	High	4	81	Planning
Capital District Transportation Authority	Albany	NY	East	185	Medium	HASTUS	High	3.5	53	Planning
MTA New York City Transit	New York	NY	East	3,866	Large	HASTUS	Medium	70	55	Planning
Toronto Transit Commission	Toronto	Ontario	East	1,317	Large	Trapeze	Medium	20	66	Operations
TriMet	Portland	OR	West	532	Large	HASTUS	High	10	53	Operations

Copyright National Academy of Sciences. All rights reserved.

For each case study site two project team members were assigned. The first team member conducted the on-site visit and developed initial documents. The second team member, who in each case was familiar with the transit system, performed a review and oversight function. The assignment of case studies was developed to ensure that project team members visit agencies of different size, complexity, scheduling system, and issues. The on-site visits involved discussions with scheduling, planning, and operations staff to gain a variety of perspectives regarding scheduling issues. Where appropriate, senior management will was also interviewed. Each case study agency had the opportunity to review and edit its draft case study report.

Four team members conducted the case studies, following a standardized approach. The case study reports have a similar but not identical structure, because each report highlights the issues of greatest interest at that agency.

E.3 Los Angeles County Metropolitan Transportation Authority Case Study

Introduction

The Los Angeles County Metropolitan Transportation Authority (LACMTA – or simply MTA) is one of the largest bus operators in North America. MTA is unique among North American transit agencies in establishing a highly decentralized management structure based on geographic “Service Sectors” roughly aligned with garage locations. Scheduling functions are similarly decentralized, with schedulers assigned to individual sectors. This decentralized approach was seen as a way of moving service decisions closer to the riding public who benefited from and in many cases were dependent on the service. The decentralization of MTA was to some extent a response to parts of its service area breaking off and forming separate transit agencies (Foothill Transit in the San Gabriel Valley is an example of an offshoot of the original MTA) and was designed to help a very large district to be more responsive to the area it serves.

Each of the five sectors has its own service planning and scheduling organization. Scheduling is headed up by a sector Manager of Schedules who reports to the Sector General Manager. Adding to the uniqueness of this structure is the fact that each sector is operated autonomously, much as a separate bus company in their day to day operation. The scheduling managers and their staff of schedulers adjust service according to passenger load requirements, do their own blocking using a computerized optimizing software routine and perform their own runcuts. A few bus lines cross sectors. In these cases, the line is scheduled by the sector having the greatest share of the line, while maintaining coordination with the other sector.

The rail system, both light and heavy rail, is operated as its own separate sector with the same structure as the bus sectors, except that the rail sector reports to an assistant general manager of Rail Operations.

Copyright National Academy of Sciences. All rights reserved.

As of August, 2007, MTA schedules the following numbers of buses or rail vehicles by time period:

		AM Peak	Base	PM Peak
Bus	Weekday	2058	1112	2089
	Saturday	943	1054	1118
	Sunday	684	837	876
Heavy Rail	Weekday	62	36	66
	Saturday	24	36	36
	Sunday	24	36	36
Light Rail	Weekday	95	50	95
	Saturday	38	50	54
	Sunday	44	50	54

Note that for rail, these are vehicle counts and not train counts. Heavy Rail uses four and six car trains; Light Rail, two and three car trains.

MTA was chosen as a case study because it is one of the largest systems in North America and includes scheduling of three separate modes. The decentralization of planning, scheduling and operations of the system is a unique aspect that may serve as a model for other large operators.

Four individuals were interviewed for this case study:

- Ed Muncy, Director of Scheduling Performance
- Roy Gandara, head of scheduling for the Central-Westside Sector, the largest of MTA's sectors that includes three divisions and extends from downtown Los Angeles west to the Pacific Ocean and north to the Hollywood Hills (separating central Los Angeles from the San Fernando Valley)
- Susan Phifer, Transportation Planning Manager IV
- Bruce Shelburne, Senior Rail Planner and the person in charge of rail scheduling

The Bus Scheduling Process

MTA uses Giro Hastus as its bus scheduling software. The software builds schedules and blocks the vehicles (called "bus runs" at the MTA). MinBus is employed to further optimize the vehicle blocks. CrewOpt is used to cut runs and roster the weekly work. At present rail scheduling is done manually with the aid of Microsoft Excel© spreadsheets.

Each scheduler is expected to be competent with Hastus as well as with building any type of schedule encountered in that sector, from the most complex to the one bus shuttle line. At the present time, schedulers have all been on the job for some time. No new scheduling employees have been brought on for the past few years, so no formal recruitment program is in place to assist with picking potential schedulers who have the core competency. Schedulers are all members of one of MTA's several unions. In this case the Clerks (TCU), a carry-over from the railroad days of Pacific Electric.

Copyright National Academy of Sciences. All rights reserved.

Scheduling Issues

Complex Through-Routing and Interlining

Los Angeles has typically used through-routing of lines in downtown to both save equipment and reduce the need for very limited curb space for layover zones. Over the years, some of the through routings devised have been quite elaborate. The present operational line 28, comprised of lines 27, 28 (West Olympic on the Westside), 83, 84, 85 (through Highland Park and Eagle Rock to the north), is a prime example. As may be expected, there are few schedulers who are able to maintain and adjust these types of lines. As well, Operations is having increasing difficulty operating these properly, given traffic conditions and disruptions. The result is that this particular line is being broken up into several discrete lines that will terminate downtown, even though it will mean losing the bus savings and tackling the issues of layover space.

As contrasted with through routings (those all day formal pairings of lines, which may also share a common line number), interlinings (random hooking of trips to save buses, particularly during peak hours) continues to be used extensively, although the agency has reduced the extent of interlining over the last three or four years. When MTA acquired the Hastus MinBus tool, they turned it on to see what could be achieved. The result was often a jumble of interlinings, which sent a bus and operator over several different, unrelated lines during a day's assignment. The result was a significant saving in bus hours and peak buses. However, the solution was highly unpopular with both operators and Operations management, as the tool might arbitrarily remove a bus from a particular line in non-peak times where recovery time was potentially too long and deadhead it to another line to fill a trip in order to achieve very minimal savings. As a result of this experience, MTA has pulled back to a more selective use of MinBus to achieve savings where it matters most – in peak periods or at times when school trippers are working into or out of the peaks. This seems to have satisfied Operations management while still holding to savings in peak requirements. The agency's scheduling statistics show a saving of 294 vehicles in the AM peak through interlining and an even greater 419 in the PM peak.

Scheduling Bus Rapid Transit

The 720-Wilshire Rapid is MTA's premiere Bus Rapid Transit route. This route uses 54 buses in the peak and provides headways as short as three minutes. The line is about 34 miles long and takes between 80 and 100 minutes in each direction. Originally, the line was scheduled without intermediate timepoints (other than for information purposes). Drivers leaving Montebello had free running time all the way to Santa Monica. The idea was to keep from slowing down the service by having to kill time at a timepoint when arriving early. As might be expected, the Operations Department has seen the need to reintroduce intermediate controlling timepoints in order to better regulate consistent headways. As is true seemingly everywhere, the driving habits of individual drivers coupled with random traffic delays can cause unacceptable bunching if the route is not controlled. MTA also added street supervision to this line as another method of regulating service. Several MTA sources indicated that additional street supervision was an effective tactic in achieving consistent headways.

MTA has a 14 mile bus rapid transit line in the San Fernando Valley which connects with the end of the Red Line subway at North Hollywood. This line is almost entirely free of surface streets, operating on a paved right-of-way, which would have been light rail if politics had not intervened. It features 60 foot articulated buses operating on three minute headways during peaks. Scheduling for this line is handled by the San Fernando Valley sector out of Division 8 in the northwest corner of the valley. It is scheduled like a bus route, with intermediate timepoints.

Copyright National Academy of Sciences. All rights reserved.

Ridership Data

MTA has a fleet that is almost entirely equipped with automatic passenger counters (APCs), from which it gleans both ridership and running time data. Usable data is captured on 70-80 percent of their trips. They also have taken a serious approach to dealing with the voluminous data that results from APC collection by assigned a full time data manager to APC data analysis. It is the data manager's responsibility to eliminate trips that are out of tolerance due to service disruptions, equipment breakdowns, etc. Schedulers can then look at a rich subset of data averaged across whatever time period they wish in developing headways and adjusting running times on any new schedule. APCs have replaced a cadre of over 100 ride checkers employed on the system 20 years ago.

Work Rules

MTA has a fairly restrictive set of work rules that govern their ability to produce efficient runcuts. The most controlling is the requirement that 60 percent of all runs must be straight on weekdays. Next is the "eight within ten" rule that requires no more than a two hour unpaid break in any split run. Any time not worked beyond that two hour period is paid at straight time, which creates a major deterrent when assembling pieces of a split. Those two requirements have traditionally caused schedulers to leave a significant amount of work as trippers. MTA has part-time employees who can work some of the trippers. In addition, smaller trippers that can be worked by operators either before or after straight runs are set aside as Biddable Trippers. When bid, they must be worked by the bidding operator just the same as his/her regular work.

MTA also has a healthy recovery requirement of 15 percent. Since there is also a requirement to provide a clear break for operators every four hours, the recovery often is purposely scheduled larger than the minimum requirement in order to keep headways consistent.

MTA has experimented with ten hour/four day runs and have a small number of them. This schedule has not proven popular, possibly because of the number of runs with platform times approaching or even exceeding 10 hours on a normal five day assignment. These have traditionally existed because of the length of some lines and because of the eight-with-ten rule mentioned previously. In the latter case, a split run with 12 hours of spread or greater would typically be constructed of close to 10 hours of platform time in order to mitigate the payment of time which is strictly a penalty and no work is being performed. In any event, there appears to be no impetus to expand the number of 10/4s on the property.

Since some work rules, such as the 60 percent weekday straight run rule, are applied systemwide, every sector must share in the effort to achieve that goal. There is some impetus for each sector's scheduling team to finish their runcuts as early as possible, so that if there is any problem in reaching the goal, the sectors finishing later have to make up the difference. In practice, the nature of the service mix in some sectors helps them reach their goal more easily. In some cases, runcuts have had to be redone after submission in order to meet the goal. What is unique is the established cooperation between the sectors, leading to a compliant overall runcut.

Copyright National Academy of Sciences. All rights reserved.

Rail Scheduling

The Rail Division schedules four rail lines, each with its own type of equipment and its own facility. Three of the lines are considered light rail, although one of the lines, the Green Line, is completely grade separated, mostly in the middle of the I-105 Freeway and is capable of automatic operation (two of the light rail vehicles have on-board control equipment to attain this, although this mode is never used). In addition, two new light rail lines are well along in planning, one of them about 70 percent complete and scheduled for a 2009 implementation.

Rail scheduling differs from bus scheduling in a number of ways. First, rail schedules employ the use of “fall backs” in constructing operator assignments (called Work Runs on the MTA). In a fallback system, the operator of an incoming train at a terminal gets off the train and “falls back” to operate either the next arriving train or a subsequent train. Using this system, the operator gets to recover even as a new crew keeps the arriving train in operation. This method allows maximum utilization of train equipment through short turn-arounds and also helps to minimize congestion at terminals from incoming trains waiting for a platform track. Thus, runcutting on rail requires separating runs from blocks and developing an intermediate “crew block” which matches the operator’s routine. Runs are then cut from the crew blocks.

Another way where rail differs is in the scheduling of diversions to handle track or infrastructure maintenance. As with a number of other rail scheduling groups, the number of diversion schedules that have to be written is far greater than the number of new or revised service schedules. They are also more complicated, as they must return crews and trains to their proper terminals once the diversion period is over.

Finally, rail scheduling also has to take into account train size. On the light rail lines, cars are regularly added and cut at the beginning and end of the day. The Blue line between Los Angeles and Long Beach normally schedules three-car trains during peaks and midday, but some peak blocks are run with two car trains. Two-car trains are typical on the other two light rail lines. The Red heavy rail line operates with a mix of four and six-car trains (the stub routing from Wilshire & Vermont to Western receives the shorter trains). Car count then becomes a major consideration when working on rail schedules.

The biggest scheduling challenge is the Blue Line running between downtown Los Angeles and downtown Long Beach over a 22 mile route largely following the path of the former Pacific Electric Long Beach line. This line presently carries well over 70,000 riders a day, making it the heaviest single light rail line in the US. The 7th Street-Metrocenter station, the inner terminal of the line, features a dual crossover located behind the station. Complex arriving and departing procedures have been developed to keep this terminal “fluid” during peak periods where headways get as short as four minutes. This will become even more challenging when the Expo line is opened and uses the same terminal from 2010. Discussions have finally begun on finishing the tunnel in which this is located to form another rail route to Union Station both to relieve the Red Line crowds and to allow for through-routing of rail lines such as the Gold line, which presently ends at Union Station.

E.4 San Diego Trolley Inc. Case Study

Introduction

San Diego Trolley Inc. (SDTI) operates fixed-rail LRT service in San Diego County. SDTI operates 33 peak multi-car units from a single yard and employs 100 full-time and 44 part-time

Copyright National Academy of Sciences. All rights reserved.

train operators. The off-peak unit requirement is 25, resulting in a relatively low peak-to-base ratio of 1.3 (which indicates a high level of off-peak service). The system operates over 51 miles of track in San Diego County and is primarily a radial system.

Organizationally, SDTI is a subsidiary of the Metropolitan Transit System (MTS). MTS is also responsible for bus operations in San Diego.

SDTI is included in the case studies because it provides an example of the scheduling process at a fixed rail system with accompanying schedule writing and blocking constraints. It also undertakes complex run cutting compared to many other systems, particularly with regard to meal breaks and multi-piece runs. SDTI utilizes the Hastus computerized scheduling software package, acquired as part of an MTS systemwide implementation. As is the case at many smaller transit agencies, one person is primarily responsible for all scheduling and service planning tasks (SDTI has no formal service planning function). The roles the scheduler is required to undertake include:

- Scheduling
- Service Planning
- Service Analysis
- Field Work

The unique organizational arrangements for SDTI (i.e., effectively being a self-contained operator but an overall part of the MTS structure) ensure there is technical support available as required, well beyond that which typically exists in a smaller transit system.

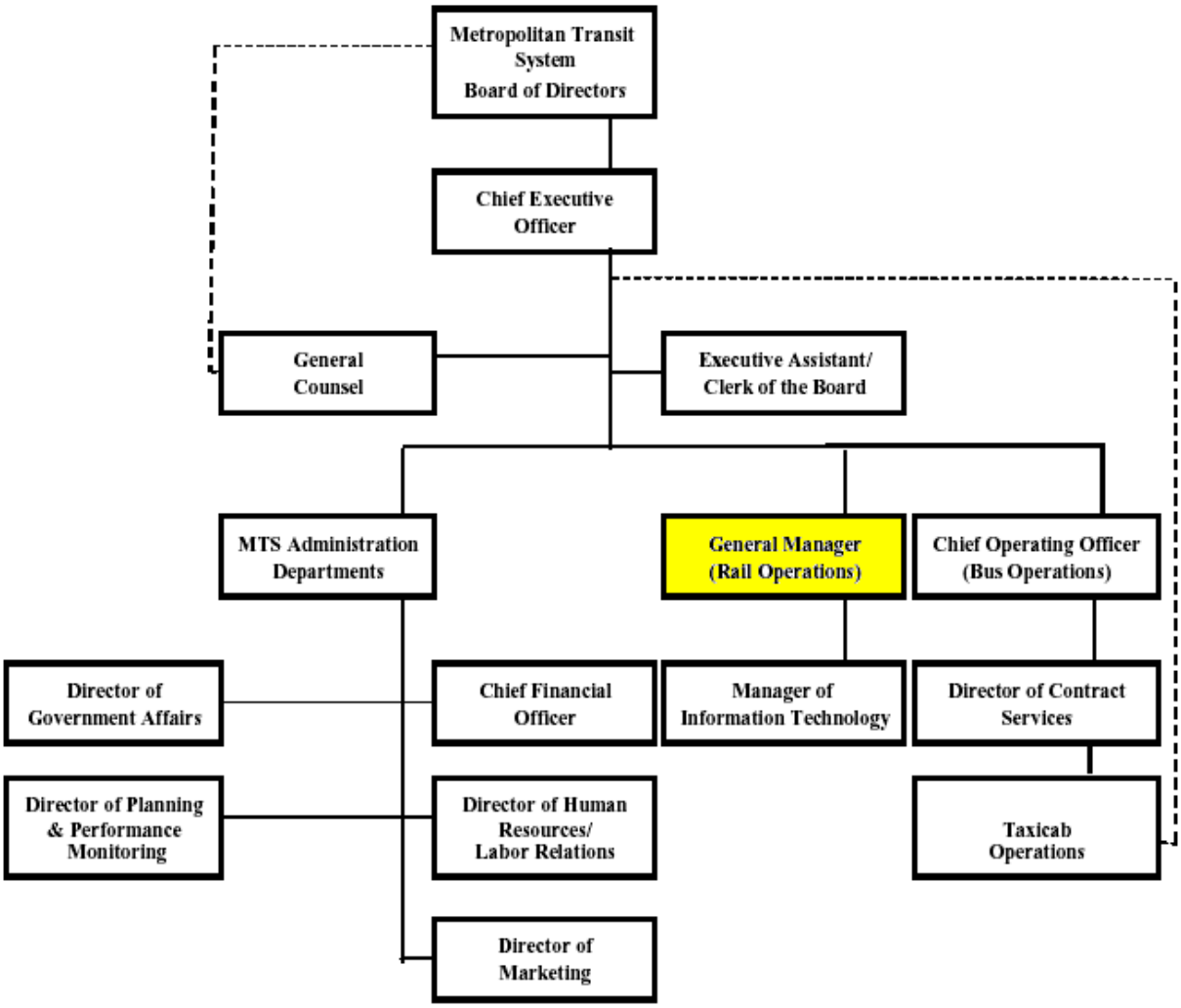
The scheduler reports directly to the Vice President, Operations. Figure E-1 indicates where SDTI fits within the overall MTS structure.

One individual was interviewed for this case study:

- Walter Clack, Schedules Analyst

Copyright National Academy of Sciences. All rights reserved.

Figure E-1
MTS Executive Level Structure



The Scheduling Process

SDTI undertakes a consistent scheduling process across its three annual bids, with minor service adjustments implemented each time. The typical bid scheduling process includes the following:

1. *Bids*. There are three annual bids. These fall in line with school term dates. SDTI is only obligated to have two bids in the labor agreement, but three bids are considered preferable due to school dates and accompanying service level changes. As is typical across many systems, the longest lead time in the process is finalizing senior level approval for any service changes.

2. *Service Design*. The scheduler is closely involved in any service design processes. At SDTI this particularly relates to service expansion (such as the recent Green Line introduction), where the scheduler has significant input into the service operating plan.

Copyright National Academy of Sciences. All rights reserved.

3. *Service Levels*. Due to system constraints (see below) the service levels and headways are highly stable. SDTI requires board approval for all service level changes. Most service levels are therefore effectively policy-based. Changes to consist lengths (i.e. the number of cars) do not require board approval and SDTI uses this as a means to deal with demand fluctuations. All services operate on a base 15-minute service and 30 minutes at night. The Blue Line operates a 7.5 minute peak service (scheduled as an alternating 7 and 8 minute headway).

4. *Running times*. Being a fixed-route service with its own right of way, SDTI is able to use average speeds and test vehicles to develop and monitor running times. The scheduler, who also serves as the operations analyst, is responsible for ongoing running time analysis tasks.

5. *Mapping* The system and stations are mapped within the GIS component of the scheduling system. This is incorporated into the MTS scheduling information and used for customer information purposes.

6. *Trip patterns*. Typical of a fixed-rail system, trip patterns and times are simple and consistent. There are three routes (Blue, Green and Orange). All trips operate the full route length, with the exception of pull in/pull out trips (which operate primarily as in-service trips) and some peak trippers starting from the yard. Additional patterns sometimes operate for special event/exception services, which are discussed below.

7. *Span of service*. All routes operate a full span of service starting from just after 4 AM and operating until almost 1 AM on weekdays. Some later trips operate on Saturday nights. As with service levels, the spans are board mandated. Span of service is also stable and requires board approval to change.

8. *Building the schedule*. For SDTI, the development of a base headway pattern that meets required service levels and infrastructure constraints is a detailed process of modeling of alternatives and reaching a consistent base pattern, which is then applied across all times of day and service types. Once a set pattern that meets the various constraints has been achieved, the schedule is relatively simple. Additional peak services tend to be added as tripper blocks. For example the 15-minute base service on the Blue Line becomes 7.5 minutes during the peak. In this case the base 15-minute pattern times are maintained and additional 15 minute service is overlaid to achieve the 7.5. There are several timed transfer locations that are systematically included in the schedules.

9. *Blocking*. Blocking is undertaken on a line by line basis and in reality is fairly straightforward, again typical of a fixed-rail system. The base blocks are created by a mix of automation and manual intervention within the Hastus system – the 18-minute layover at San Ysidro is enforced by manually hooking the trips at that location. The additional peak services on the Blue Line are blocked as standalone trippers so as not to affect the regular blocking pattern.

10. *Runcutting*. Hastus is used to produce automated runcuts. SDTI uses a relatively sophisticated set of rules to develop runcuts. For example, it uses 20 different categories of run, each with specific constraints and preferences. SDTI feels this approach gives it more control over the solutions produced. Many solutions are run for each run cut, each time with minor rule adjustments or preferences altered. This becomes a highly iterative

Copyright National Academy of Sciences. All rights reserved.

process until the scheduler is satisfied that the outputs meet SDTI's efficiency and operational requirements. The weekday runcut has 69 full time and 21 part-time operators. Weekday Pay/Plat ratio is 1.17.

11. *Rostering*. Rostering is based on a cafeteria-pick process for full time operators. Operators first pick to be AM or PM, and then within those categories get to pick daily runs. Part-time runs, however, are packaged into rostered weekly lines of work by the scheduler. Part-time operators then pick the lines of work. There are typically 3-4 runs in a line of work (each run can be up to 7:45). The leftover days/hours are used to cover absences and events.

Key Scheduling Issues

Schedule Constraints

The most significant scheduling constraint SDTI faces is the impact of operating a fixed-rail, signalized service across a network with multiple junctions and intersecting routes. The impact of this is that once a service pattern is developed that allows for these constraints, the schedule is 'locked in' in terms of timetables. There are four multiple route junctions with potential track conflicts, in addition to a section of single track beyond El Cajon. In addition to the infrastructure constraints there are three key timed-transfer locations.

A further constraint is the mix of older and newer fleet types, with high/low floor differences and platform accessibility issues. This further complicates service design and limits scheduling flexibility.

A final constraint refers to the track section shared with freight train services. The SDTI service shuts down between 2 AM and 4 AM to accommodate this requirement.

The complexity of schedule development, caused by the system constraints, dictates the need for the scheduler to be involved in the service design process from a very early stage and to have ongoing input. Any timetable change, potentially of even one trip by one minute, can have a series of downstream impacts across the entire network.

For SDTI the development of a base headway pattern that meets required service levels and infrastructure constraints is a detailed process of modeling of alternatives. Once headways are finalized the timetables are highly stable, with very few changes. Typical changes tend to be the number of cars operating on a trip rather than any change to service levels or headways. For example, the January 2008 service change includes: the last two eastbound and westbound trips between Old Town and SDSU are discontinued, seven days a week.

Running Times

SDTI operates on its own right of way, which means that running times are much more predictable than on a bus system that interacts with traffic. The most significant factor affecting running time variations are station delays during the peaks (due to higher boardings and alightings), and increased wheelchair patronage.

To develop running times, SDTI undertakes operating tests (to establish running times from station to station) and then adds in average delay times at stations, based upon operating data and experience. Running times are set for the entire day based on peak time demands. This

Copyright National Academy of Sciences. All rights reserved.

results in some excess time during off peak and (more likely) early/late services. However, the agency is comfortable with this approach as most maintenance occurs at these times and some running time buffer is beneficial to keep the system operating reliably.

Where new lines are opened, the scheduler works with operations staff to predict running times. The recent Green Line extension is a good example of this process and the estimates proved to be accurate. Further running time analysis after the line opened allowed minor refinements.

The scheduler undertakes an ongoing program of review and analysis of operating data to monitor running times.

Layovers

Layovers tend to 'fall out' of the schedule-writing process, due to the constraints of schedule development. SDTI policy requires a five-minute minimum turnaround time. The (minimum) 5-minute turnaround at Old Town would have resulted in either a three-minute turnaround at the San Ysidro terminal or dropping back a headway, resulting in an 18-minute layover. To maintain the five-minute minimum turn time, SDTI effectively moved the linkup back by one trip, resulting in an 18-minute layover at San Ysidro. This also assists with operator break requirements. SDTI uses operator drop backs to ensure operator rests (the exception being the San Ysidro case discussed above). Interestingly the high numbers of reliefs that result from this process do not appear to result in any noticeable reliability impacts.

Interlining

There is no interlining in the system. Each of the three routes is scheduled on a standalone basis. The potential for interlining exists at Old Town (between the Green & Blue Lines), but vehicle type and infrastructure limitations preclude this option.

Work Rules

SDTI operates with a set of basic run cut rules that include the following basic components:

- Full time runs are between 7:46 and 9:20 worked hours
- Part-time runs are less than 7:46
- Break requirements of one 30-minute and two 15-minute breaks (see below)
- Report time of 7 minutes for a relief and 10 minutes for a pull-out
- Maximum piece lengths of 2:34

Exception/Events Scheduling

Exception (primarily events) scheduling is an ongoing issue for SDTI. There are numerous sports events (soccer, football, baseball) that require additional services. SDTI now has a number of template schedules used for various events. These can then be manipulated for the particular intricacies of a specific date or event.

The additional resources required to operate additional events services are covered by two methods:

Copyright National Academy of Sciences. All rights reserved.

1. If the event is known well in advance, the schedules and runs are built into the Hastus system and form part of the bid.
2. For more ad-hoc or short-term exceptions, part-time operators are used to cover some manually-created pieces of additional work. This approach is made simpler by the base runs being created in an 'event friendly' manner, based on the experience of the scheduler (e.g., creation of shorter PM part-time runs, with capacity to have additional work added).

Part-time operators are used to cover events as much as possible. This allows more flexibility for altered start/finish times, days of work, etc.

The use of automated Daily Operations/Dispatch modules requires some further work-arounds to handle events/exceptions. Additional 'event activity' pieces are created and added to the shifts on the day of operation.

Yard Shifts

Being a fixed rail service, SDTI has a requirement for Yard Operators, whose primary functions include:

- Safety inspection and vehicle setup
- Coupling/uncoupling of vehicles
- Cuts/adds

The Yard Operator requirements are built into the schedule as blocks of work in notional 30-minute trips. This allows Hastus to cut pieces of yard work and incorporate them into the operating runs (manual manipulation of these also occurs). The number of Yard Blocks built into the schedule varies across the day according to need, and based on SDTI operating experience. There are between three and seven 'blocks' of yard work at various times during the day. The pieces tend to be outside the peak as the nature of the work tends to be pre- and/or post-peak.

Meal Breaks

SDTI is subject to California's legislated meal break requirements. However, unlike other operators who have not historically provided breaks, SDTI has been scheduling breaks for almost 15 years.

The requirement is for operators to have one 15-minute (paid) break and one 30-minute (unpaid) break in each run. An alternative allows for three 20-minute breaks in a run. SDTI keeps a few 20-minute break runs, primarily to ensure this option is kept open for the future.

The policy applied at SDTI is that operators receive one 30-minute (unpaid) and two 15-minute (paid) breaks in each run. The 15-minute breaks are built into the schedules in the following manner:

- Blue Line. There is an 18-minute layover at San Ysidro.
- Green Line. Operator dropbacks on a five-minute layover allow a 20-minute break.

Copyright National Academy of Sciences. All rights reserved.

- Orange Line. Operator dropbacks at 12th/Imperial allow an 18-minute break. 12th/Imperial is a midpoint at the start of the loop through the city, so operators basically have the following pattern of work pieces:
    - A trip from the outer terminal to 12th/Imperial
    - Relieved at 12th/Imperial and have an 18-minute break while the vehicle does the loop
    - Relieve again and operate the remainder of the trip to the outer terminal

The 30-minute break must not be within two hours of starting a run.

The meal breaks and dropbacks result in multi-piece runs and a relatively complex and sophisticated run cut. The longest individual piece is two hours and 34 minutes, which equates to the longest round trip in the system.

A final complexity added to scheduling of breaks at SDTI is that yard pieces (see above) can be incorporated into a run and counted as mealbreak time.

SDTI analysis has showed the cost impact of mealbreak requirements to be relatively small – on the order of two to three percent. This is due to the fact that the primary (30-minute) meal break is unpaid and the two 15-minute paid breaks fall within layovers.

Part-Time Operators

There are 30 part-time operators. Part-time operators cover the extra board. Because of staff shortages and available tripper runs, part-time operators work significantly more than 'part-time' hours. There are few contract limitations on the use of part-time operators, other than the base PT runs should be 7:45 or less in work time.

Extraboard

SDTI is unique in that it has no scheduled or permanent extraboard. Part-time operators are utilized to cover absences. The absence of any restriction on weekly part-time operator hours allows this approach. Part-time rosters are built with enough spare time (based on experience) to allow coverage of absences in this manner.

.

Use of Overtime

The traditional preference at SDTI is to have the duties as close to eight hours as possible.

However, in the previous several years unemployment has been low in San Diego. SDTI has therefore had a difficult time finding qualified new employees and has been understaffed. To make up for this understaffing, SDTI has created longer duties.

As the employment picture changes, and staff increases closer to authorized levels, SDTI will again try for duties as close to eight hours as possible.

SDTI's overtime rate is 1.5 times regular rate. Most fringe benefits are fixed, based on a forty-hour week and eight-hour day. Therefore, the only potential costing impacts accrue from fringe benefits related to wage rates.

Copyright National Academy of Sciences. All rights reserved.

Computerized Scheduling

SDTI moved to the Hastus system in 2004. Implementation went smoothly with a limited parallel testing period.

Use of the Hastus system has been highly beneficial in developing more efficient run cut solutions. This is not surprising, given the complexity of the rules and the multi-piece runs used by SDTI.

The scheduler uses the system in both an interactive and automated manner, as required or appropriate for specific tasks. The SDTI scheduler uses the system in a highly iterative manner, with a variety of approaches and constraints, to produce run cuts. For example a set of 'preferable' part-time runs may be manually created before submitting the run cut.

Planning for rail services has long been undertaken using time-distance charts and this functionality is utilized by the scheduler for service design & planning.

One area of significant effort in the implementation of computerized scheduling at SDTI (and at MTS) has been "day of operations" scheduling. The "day of operations" module provides an interface with the regular schedules to manage daily changes (due to operator absences, service disruptions, or any other reason) in real time. The challenge in implementing this concept has been that the boundaries around "day of operations" scheduling tend to be less defined than traditional scheduling. The operations staff, not the schedulers, is generally responsible for these decisions. The benefit is that computerized approaches to "day of operations" scheduling open up a range of previously unknown (or unachievable) alternatives.

Downstream Requirements

There are a number of downstream systems that use the scheduling data across the MTS implementation. These include:

- AVL
- APC
- Headsigns
- Voice Annunciation

SDTI is not part of the AVL implementation and is instead investigating some rail-specific Train Location Systems, based on track circuitry.

At many transit systems the impact of these systems has been to increase the scheduling workload. This is not as big an issue for SDTI – there is no route deviations/variant complexities, the stops (stations) and right of way are fixed, and the headways are highly stable. The one-to-one stop-to-timepoint correlation also simplifies the issue of patterns and variants significantly.

Therefore many of the ongoing issues with downstream systems do not occur. As a result the burden on the scheduler of these downstream systems is not as high as for many bus operations. Impacts have been limited to issues such as changing block or run-numbering schemes (due to keeping multi-agency unique numbers).

Copyright National Academy of Sciences. All rights reserved.

Management of stops data is not the responsibility of the scheduler, but is handled by technical staff.

Organizational Issues

SDTI scheduling's most significant organizational issue is the reliance on a single scheduler. This reliance is exacerbated by the fact that the scheduler's role also covers service planning, operations analysis, service monitoring and a variety of related tasks.

The impact of this situation is the lack of a succession plan for scheduling, or backup for the scheduler. This is a typical situation faced by many small transit properties.

SDTI is currently undertaking training of an assistant to reduce exposure in this area.

Mode-Specific Issues

As a fixed-rail operator, SDTI deals with some rail-specific issues. These have been mostly described in sections above but can be summarized as follows:

1. *Conflict Issues*. Described in detail above, the presence of track and signaling constraints imposes significant limits on schedule development and the ability to alter headways.

2. *Coupling/Uncoupling*. SDTI operates consists of varying lengths, according to demand. This is an ongoing process of refinement and adjustment. Changing consists requires coupling and uncoupling activities. These must be covered in the scheduling process. At SDTI, yard crews are used to undertake these tasks (as part of a broader set of daily tasks). The coupling/uncoupling tasks are manually created and assigned within Hastus by the scheduler. Notes are added to paddles to inform operators of these requirements.

3. *Consist Size*. SDTI operates different sized units at certain times of day. These can be summarized as follows:

    - Green Line: two-car sets all day
    - Orange line: two-car units off peak, three or four-car units during the peaks
    - Blue Line: three-car units all day, two-car units at night (after 9pm, except for special events)

4. *Vehicle Types.* Operators of rail systems tend to have stronger vehicle type restrictions than buses, as rail cars tend to be less 'substitutable' than buses. SDTI is a good example, where the newer low-floor vehicles can operate only on specific portions of the network, placing an additional scheduling limitation.

SDTI Input on What the Scheduling Manual Could Include

There were several issues noted that SDTI staff would like to see covered by the updated manual. These include:

- Analysis of the issues, benefits and optimal use of part-time operators
- Consideration of career progression for schedulers

Copyright National Academy of Sciences. All rights reserved.

- Alternative approaches to use of computerized scheduling tools
- Discussion of recent workforce trends (higher wages, difficulty in attracting staff)
- How to deal with interfaces to downstream systems
- How to look outside normal practices and think laterally when undertaking scheduling tasks
- Training for service planners in how to develop basic what-if scenarios

E.5 City of Santa Monica Big Blue Bus Case Study

Introduction

The City of Santa Monica's Big Blue Bus provides transit service primarily in Santa Monica, CA and in adjacent areas. The City of Santa Monica is part of the greater Los Angeles metropolitan region.

The Big Blue Bus operates 147 peak buses from a single garage and employs 233 full-time and 30 part-time bus operators. The daytime bus requirement is 88, resulting in a peak-to-base ratio of 1.7, higher than usual for a smaller system. The system is typical of local municipal agencies around Los Angeles in that it relies on the regional operator (Los Angeles MTA) for funding. Therefore MTA has some input into service levels and service design (the introduction of the Lincoln Rapid service is an example).

The Big Blue Bus is included in the case studies because it provides an example of the scheduling process at a small-to-medium transit agency. In addition, it is well regarded throughout the industry. Big Blue Bus utilizes the Trapeze computerized scheduling software package. As is the case at many smaller transit agencies, one person is primarily responsible for all scheduling tasks, with a crossover role into service planning (which too is primarily undertaken by one person). However, being larger than 'small' transit systems, there are also staff and resources available for technical support roles, which smaller agencies tend not to have.

Four individuals were interviewed for this case study:

- Richard Newton, Senior Transit Analyst (Scheduling)
- Bob Ayer, Transit Services Manager
- Paul Casey, Senior Service Planner
- Benjamin Steers, Transit Systems Analyst

The Scheduling Process

Big Blue Bus takes the approach of using the Trapeze system interactively for schedule writing and blocking, and in a more automated (although still iterative) manner for run cutting. Interactive use of the system can be described as the scheduler using the system to replace manual processes, but not using all automated features of the system – for example, manually hooking trips instead of using the automated blocking function.

The timing of the scheduling process is dictated by the four annual bids required. The following is the process followed by Big Blue Bus, leading up to a 'typical' schedule revision and "pick" by operators.

Copyright National Academy of Sciences. All rights reserved.

1. *Bids*. There are four annual bids at Big Blue Bus. The bid timelines require service changes to be agreed and finalized 102 days before implementation - note that each bid commences on average only 91 days after the previous – meaning in effect for some bids the service changes need to be finalized before the previous bid has been implemented.. Typically, there are only three weeks for the scheduling work to be undertaken, allowing very little room for meaningful alternatives analysis.

2. *Service Levels*. Service levels are a mix of demand-based and policy-based. Big Blue Bus operates a minimum 30-minute headway. Some services drop below the policy level for a few early or late-night services. As MTA provides funding, and also operates its own services in the area, some collaboration is undertaken in determining service levels (in some cases MTA may dictate service levels). Senior management tends to take responsibility for major service level decisions, with some input and advice from the scheduler and service planner.

3. *Running times*. Running time adjustments are based upon four main input sources: paper-based field checks, NTD random sample surveys, operator complaints, and AVL data. The AVL outputs are somewhat limited as the reports show early/late information at timepoints, and not end-to-end running times. In addition there are no graphics or formats that can be manipulated, only pdf reports which are then typed back into spreadsheets. The scheduler tries to work to averages for running time adjustments.

4. *Mapping*. All routes are mapped in the Trapeze system. The Trapeze mapping component is primarily used for producing operations information such as AVL exports, route distances, and stop-related data. Big Blue Bus also has internal mapping tools for service planning and analysis purposes.

5. *Trip patterns*. Big Blue Bus tends to develop services with single trips patterns where possible for ease of understanding. Some short trips operate, but typically only as early or late positioning trips.

6. *Span of service*. The core routes in the Big Blue Bus system operate over long service spans, typically from before 6 a.m. until after 11 p.m. on weekdays. There are three peak-only commuter routes. Most routes operate seven days a week (with the exception of the commuter routes). Weekend service spans are similar to weekdays. The relatively high daytime service levels mean that transfers between routes can occur without coordinating or “pulsing” schedules.

7. *Building the schedule*. The scheduler builds all schedules. Schedules are built interactively (i.e., trip by trip) using the Trapeze system. The service is relatively stable and typically only minor adjustments and refinements are undertaken. The night service requires several route meets downtown, including midpoint layovers.

8. *Blocking*. Again blocking is undertaken using Trapeze in an interactive manner. Little interlining occurs and blocking is undertaken on a route or line basis. There are several peak trippers (mostly, but not entirely, school-based) that are scheduled as standalone trips for run cutting and bidding purposes. They are also used to effectively cover the peaking factor.

9. *Runcutting*. The use of Trapeze has reduced the time taken to complete run cuts from weeks to a few days. The run cutter used is not the fully automated version, but the

Copyright National Academy of Sciences. All rights reserved.

partially interactive one. This means the runs are cut iteratively and reviewed at each stage. Runs are cut on a route basis. Again the trippers are used to cover the peaks. Currently, the peak-to-base ratio is 1.1077.

10. *Rostering*. Rostering is based on a cafeteria – pick process at Big Blue Bus. Operators must take the same run at least four days per week. Operators can bid on biddable trippers as permanent overtime. The bid process is open for two weeks.

Key Scheduling Issues

Running Times

Running times have increased markedly in recent years. Big Blue Bus's peak bus requirement has increased from 96 to 147 over the past 10 to 12 years. The majority of this resource increase is due to additional running time requirements.

Congestion is the primary reason for running time increases, but the introduction of (slower) alternative fuel buses has also been a factor.

Running time analysis is limited by the outputs available from the AVL system. In particular, the fact that the AVL system only provides early/late data, and not end-to-end running times, minimizes the benefits of the data set. In addition, there is no data dump from the AVL system back into analysis – only a pdf output that is then typed manually into an excel spreadsheet.

Averages are used to generate revised running times.

Layovers

Big Blue Bus tends to take a conservative approach to layovers and blocking. There is no contractual requirement or minimum. On the longer lines, with run times of 60-90 minutes, layovers may be set as high as 20 minutes to ensure service reliability.

In order to allow for sufficient layover on some lines the schedule is adjusted, and headways become uneven (e.g. 30/30/30/35/30/30).

There are some mid-point layovers, particularly for late evening services where meets are required.

Layover currently represents approximately 17 percent of platform time. This reflects the Big Blue Bus conservative approach to layover and recovery time, given that there is no contractual requirement.

Interlining

Big Blue Bus does little interlining. Schedules are not built to interline (although there are some route endpoints served by multiple lines). There are some routes that are effectively an interline between two routes either side of downtown Santa Monica, that have been combined to minimize overlap and congestion. However, on some of these routes the uneven demand balance has resulted in higher frequency being carried for the entire length of the route. An example is Line 2, where the Wilshire Boulevard segment has significantly higher demand than the segment south of downtown.

Copyright National Academy of Sciences. All rights reserved.

Work Rules

There is basically one type of full time run where the operator works 8 hours within a spread of 10 hours (as per the MTA). In effect this means that if the break between two pieces is longer than 2 hours, the amount over 2 hours is paid. This applies to both straight and split runs.

Where the time between two pieces is 29 minutes or less, the time is paid straight through.

For a tripper combination the requirement is for 8 worked hours in an 11-hour spread.

The current run cut has 103 one-piece straights and 54 splits. There are 33 trippers.

School and Exception Scheduling

Several routes serve the campuses of Santa Monica College, a major demand generator. The day of week and school semester changes result in a significant number of variable service exceptions. These add complexity to the scheduling task and to downstream data systems.

Trippers

As mentioned above, trippers are used to cover the peaks, both for school and regular services. There are currently 33 trippers in each peak. These trippers are biddable and operated as overtime. Trippers can be a maximum of 3:45 in duration. The dual PM Peak (school and then regular service) results in some trippers that are in effect two separate blocks, with a pull-in and pull-out.

Meal Breaks

Currently meal breaks are not used. Big Blue Bus and the union have reached an agreement to avoid state meal break law requirements. Operators viewed meal breaks as increasing their spread of work without increasing pay.

Extraboard

Extra board sizing is based on operations experience. Currently the extra board is 17.7 percent of regular runs. Long term absences account for half this total. BBB feels that the extra board could perhaps be larger, but this is difficult to achieve given current operator shortages.

Some regular trippers are left for the extra board to cover, simply as a result of not being selected during the bid process.

There is a separate vacation relief board, meaning the extra board deals to a greater extent with unplanned absences/issues.

Use of Overtime

Big Blue Bus takes an organizational view that cutting longer runs and incurring overtime is preferable to adding operators. Analysis has shown that base benefits are over 35 percent, and that there are ongoing difficulties in attracting operators. The average full time weekday run length is around 9 hours.

Copyright National Academy of Sciences. All rights reserved.

Part-Time Operators

At BBB, part-time operators are limited to 20 percent of the total budgeted FTEs, which is now at 249. This allows 50 part-timers in total. There are currently 25 with nine more in a training program. Part-timers can work any piece of work (uncovered runs, people on worker's comp leave, or sick) and receive overtime if they work more than 8.0 hours per day.

Part-timers are budgeted at 0.5 of an FTE, but receive full benefits, with pro-rated sick and vacation leave only. Currently at BBB, part timers are actually working 40 to 60 hours per week due to operator shortages. Part-time operators are paid at a lower rate ($2 per hour less) than full-time operators.

Part-time drivers are valued because once extra board assignments are allocated by seniority, part-timers can work anything at any time. There are no permanent part-time only assignments; all part-timers are expected to promote to full-time when there is need for them.

Per city policy, all new hires are probationary for the first year. Part-timers can be promoted to full time before one year, but then continue as probationary full-time drivers until their one year is up. Recently the trend has been for part-timers to move to full time status anywhere from eight months to one year after starting as part-timers.

Even with this approach BBB has only 225 FTE's filled, leaving 24 vacant full-time positions (and of those 225 bodies, 30 to 45 are out on short-term sick, long-term sick or worker's comp at any one time). BBB is reluctant to promote more part-timers because they are more flexible for assignments than full time staff.

Bidding Issues

There is an issue with uncovered runs on Fridays. If operators bid Monday-to-Friday work, four days must be identical. Past practice allows operators to pick a run plus a biddable tripper on Monday-Thursday and only one of these two on Friday, leaving the other piece uncovered. This results in either very high levels of overtime or uncovered trips on Fridays (particularly during staff shortages).

Computerized Scheduling

BBB moved to the Trapeze system in 2004. First schedules were produced in 2005 after an initial parallel processing process.

The system has allowed a significant reduction in the time taken to produce run cuts. BBB uses the interactive run cutter (not the Blockbuster module), and is satisfied with its performance. However the basic run cutter has difficulty with multi-variable problems (such as meal breaks) and therefore may have limitations in the future.

Some issues with downstream systems have occurred, for which workarounds have been developed. An example is the strict control required over pattern names, which are then used by the AVL system to infer some data.

Management of bus stops data is not the responsibility of the scheduler, but is handled by technical staff.

Copyright National Academy of Sciences. All rights reserved.

Downstream Requirements

There are a number of downstream systems that require scheduling data to function. These include:

- CAD/AVL
- APC
- Head signs
- Voice annunciation

It was noted that the paradigm shift where scheduling data now extends beyond the scheduling department has affected the entire organization.

As is the case at many other agencies, the impact of these downstream systems has been to increase the scheduling workload. The scheduling process now includes a time-consuming data manipulation, maintenance and transfer role. There are ongoing data synchronization issues between the key systems, resulting in the need for scheduling tasks to be finished much earlier for each bid.

The high number of exceptions and exception combinations has been a challenge for integrating the Trapeze system with the AVL system.

The level of scheduling data accuracy and integrity requirements are now much higher. For example, simply changing a pattern name in Trapeze can have impacts on downstream systems. Some issues have arisen in route naming, interlines, and pattern definitions as a result.

There have been ongoing issues in synchronizing the scheduling system data and the APC data. These tend to relate to how data is defined in Trapeze (e.g. pattern names), and how the data transformation process deals with ongoing scheduling changes.

Organizational Issues

Service planning would like the capacity to run many more what-if scenarios. However, the sole scheduler is fully utilized in managing each bid and undertaking general scheduling tasks. Being a one-person scheduling department, the scheduler not only has to undertake scheduling work, but also executes numerous maintenance/production tasks. The result is that the scheduler is limited to providing costing information for intended services, rather than being able to undertake a sensitivity analysis.

Typical of many smaller systems, there is an issue around succession planning. The agency relies heavily on the incumbent scheduler and service planner, with no obvious replacement either available or being developed. This view was noted as a concern across all departments.

From a scheduling perspective one of the main issues is the need to have senior management make decisions in time to incorporate during the development of bid schedules.

Copyright National Academy of Sciences. All rights reserved.

The creation of a "Service Improvement Plan" committee comprised of staff from management, scheduling, operations and planning, has assisted in bridging some organizational issues. The committee oversees service level and routing decisions.

Labor Relations

Big Blue Bus has had some recent successes with a more consultative approach to labor relations. This has meant a more inclusive approach earlier in the scheduling process and not simply providing a completed set of scheduling outputs for union review.

In particular, the union has been engaged in quality control and has responded positively, particularly when they found an error of significance!

The major ongoing labor issue is that of running times. There also tends to be a tendency for some operators to consider 'layover' as "their" time, taking the full amount of scheduled layover regardless of when they arrived at the terminal.

The meal breaks process was an example of successful cooperation. Management created a draft run cut and showed the unions how the runs would look. Both sides agreed this would not be a good outcome and reached an agreement to avoid the need for meal breaks.

Big Blue Bus's Views on What the Scheduling Manual Could Include

There were several issues noted that BBB staff would like to see covered by the updated manual. These include:

- Daily operations scheduling techniques and issues
- Optimal extra board size calculation
- Efficiently dealing with school day exceptions, both from a scheduling and data management perspective
- Recent workforce trends (higher wages, difficulty in attracting staff)
- How to deal with interfaces to downstream systems
- How to look outside normal practices and think laterally when undertaking scheduling tasks
- Training for service planners in how to develop basic what-if scenarios

E.6 Regional Transportation District (Denver, CO) Case Study

Introduction

Denver's Regional Transportation District (RTD) is a complex urban system operating light-rail transit (LRT), local and express fixed route, and the 16th Street Mall Shuttle running rubber tire vehicles in a dedicated right-of-way crossing major downtown streets. Bus system design features include a combination of grid and radial trunk lines, suburban feeder routes with timed transfers at LRT stations, and park-ride express services. The system is dynamic as Denver Front Range communities continue to grow in population and traffic congestion.

RTD covers a 2,331 square mile service area containing 2.6 million residents. The District encompasses 40 municipalities in six counties plus 2 city/county jurisdictions. There are 76 park-and-ride facilities and 10,329 bus stops covered by 170 fixed routes, including 96 local, 25

Copyright National Academy of Sciences. All rights reserved.

express, 18 regional, 15 limited, 11 miscellaneous and five Airport express (SkyRide). Regular weekday fixed-route service operates 166,571 scheduled miles per average weekday, and 50.7 million miles annually, including LRT and the mall shuttle. The system operates seven days per week with 24-hour service on selected urban lines.

RTD owns 1,060 regular route buses, of which 624 are operated directly and 436 are leased to contract service providers (one-third of fixed route system bus operations are contracted out per State law). The peak requirement is 862 buses, including standard heavy-duty transit, over-the-road and smaller light-duty buses, as well as clean-fuel mall shuttles. The bus system complements an expanding LRT network that currently operates in two major corridors with 35 miles of track, 37 stations and 91 vehicles. Total passenger boardings average 312,000 per weekday, of which approximately 206,000 are on the fixed route bus system, 56,000 on LRT, and 50,000 on the mall shuttle.

RTD is included among the case studies because it provides an innovative staffing model for the service planning and scheduling functions. The Service Development Division includes both Planning/Scheduling and Technology/Data Collection managers and staff. Within Planning/Scheduling, ten positions are organized geographically into three service development teams, with each team including a senior planner scheduler, a planner/scheduler, and a schedules analyst. RTD also has extensive experience scheduling concurrently for both in-house and contracted operations.

Ten individuals were interviewed for this case study:

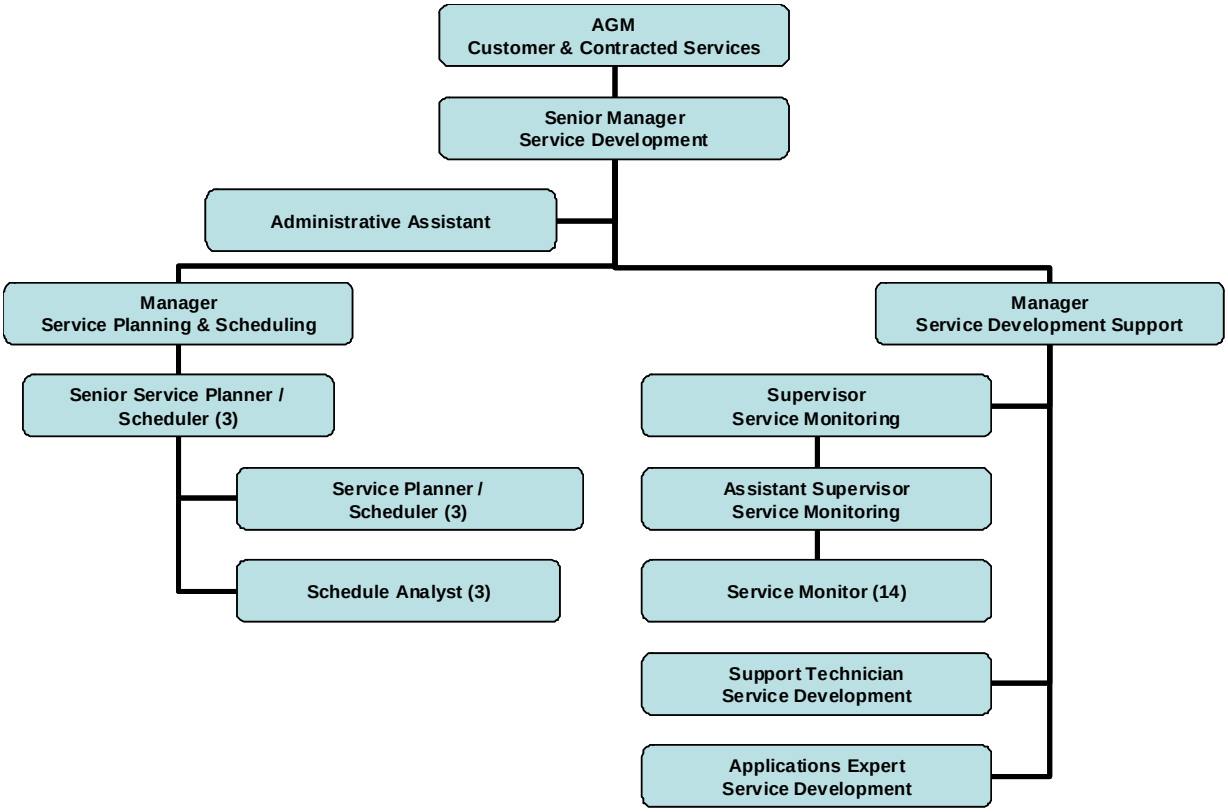
- Jeff Becker, Senior Manager, Service Development
- Bill Porter, Manager of Service Planning & Scheduling
- Bob Rynerson, Senior Planner/Scheduler – West Team
- Jessie Carter, Senior Planner/Scheduler – East Team
- Jeff Dunning, Senior Planner/Scheduler – North Team
- Nataly Handlos, Planner/Scheduler – West Team
- Bill Hoople, Planner/Scheduler – East Team
- Cesar Ochoa, Planner/Scheduler – North Team
- Eric Miller, Schedule Analyst – West Team
- Greg Smith, Schedule Analyst – East Team
- Chris Marko, Schedule Analyst – North Team

The Scheduling Process

Scheduling is part of the Customer Service and Contracted Services Department within the Service Development Division, as shown in Figure E-2. Other functions within the department include marketing and public information, customer service, and short-range transit planning.

Copyright National Academy of Sciences. All rights reserved.

Figure E-2
RTD Customer Service and Contracted Services Department Structure



The Service Planning and Scheduling section within the Service Development Division is responsible for generating headways and blocking vehicles for all lines, including contract services that comprise half of all bus operations. Division personnel also cut the runs for RTD direct operations, while the private contractors handle runcutting for their own operations. The rostering function is minimal since RTD operators pick their work cafeteria-style.

RTD staff has extensive experience with computerized scheduling and run cutting dating back to 1979. The current scheduling process is automated. RTD planner/schedulers use Trapeze FX for headway generation and vehicle blocking, and both Blockbuster and its older Fortran-based Ramcutter software. Running time data from Trapeze and actual ridership and running time data from the automatic passenger counting (APC) equipment on many RTD buses are uploaded into RideCheck Plus, a customized database software.

Service planning and scheduling are fully integrated activities at RTD. Ten staff members are organized into three geographically-based teams (North, East and West) of three persons each, plus the Manager of Planning and Scheduling. Each team includes a Senior Planner/Scheduler, a Planner/Scheduler, and a Schedule Analyst. The Senior Planner/Scheduler generally works as the team lead, with oversight and technical assistance provided by the Manager as needed. The team concept is used for all bus network planning and scheduling, but is not used to schedule LRT or Mall Shuttle services.

The geographic basis for team organization was implemented in 1990, when an early retirement program offered by the RTD Board led to the sudden loss of approximately one-third of the

Copyright National Academy of Sciences. All rights reserved.

white collar workforce agency-wide, including nine of 14 scheduling personnel. The five remaining schedulers, plus an intern (now the East Team Senior Planner/Scheduler) were reorganized into the Customer Service Department. Schedulers traditionally were non-represented positions at RTD, and remained classified as management personnel following the reorganization.

Service Design

Prevailing service design characteristics include the use of clockface headways running 15, 30 or 60-minute intervals, and a 15 to 17 percent system-wide recovery time target. The minimum standard for recovery time is 10 percent on a per trip basis, although occasionally this may be reduced to eight or nine percent as a stop-gap measure to make a schedule work. RTD does not distinguish between recovery time and layover time.

Most service planning projects involve routes that fall within a single geographic sector, and are assigned to the North, East or West Team as applicable. Most routes are either operated directly by RTD or by a single contractor, however, some routes are run by multiple providers, and the route cluster including #28/32/38/44 is run by multiple RTD and contractor garages. These projects may be assigned to a single team, or two or more teams may share responsibility.

Most lines operate on static headways and operators follow a run paddle generated by the Trapeze scheduling system. Notable exceptions include peak-period departures of primarily express buses from the two downtown transit stations (Civic Center and Market Street) and the 16th Street Mall Shuttle, which are handled with headway schedules rather than static schedules. Station Operations personnel dispatch departures on a demand basis from Civic Center and Market Street, where digital clocks are set for all buses to depart one minute late. Train card software automatically adds one minute to Trapeze times. The Mall Shuttle operation is discussed separately later in this document.

Runcutting

The agency is thoroughly experienced with computerized runcutting. The last fully manual run cut occurred in 1980. RTD operators, as well as operators working for two of the three contractors are represented by the Amalgamated Transit Union (ATU); the third work force currently is non-unionized. RTD operators belong to ATU Local 1001 and covered by a collective bargaining agreement that extends through 2009. Key parameters affecting run composition include:

- A regular run is defined as a scheduled piece or combination of work having seven or more platform hours per day and paying a minimum of eight hours per day, including allowances for deadhead cushion, sign-up and intervening time.

- A minimum of 55% of all weekday runs and 65% of weekend runs must be straight runs. Meal breaks are not required under the collective bargaining agreement, so that straight runs generally consist of one piece. These percentages are calculated separately for bus and rail.

- Split runs may consist of two or three pieces, provided that no piece is longer than 6:59. In the case of three-piece runs, the shorter of the two breaks are paid as intervening time at the straight time rate.

Copyright National Academy of Sciences. All rights reserved.

- Work not designated as part of a regular run is posted on the extra board.

Use of part-time operators is allowed by the collective bargaining agreement. The maximum number of part-time operators is limited to 21 percent of total the number of full-time bus operators. Part-timers may work up to 30 hours per week and generally are limited to working weekday peak period trippers and weekend runs left over following the full-time operator pick. Some part-time runs are one piece straights paying under six hours, while others are splits containing a morning and afternoon tripper.

Scheduling Issues

LRT System Expansion

The LRT system was expanded dramatically in November 2006 with the opening of the Southeast Line. The project was part of the "T Rex" package of traffic and transit improvements in the I-25 corridor. Initial planning was done in 2001 to accommodate the "design-build" contracting process, and insufficient staff was available at the time to develop detailed plans. For example, signs to designate bus stops at the stations were overlooked.

The LRT changes affected 72% of all bus routes. All three teams became the East team and worked together beginning in March 2006 to prepare for the November implementation. No significant service changes were undertaken in August 2006. In retrospect, the bus planning should have begun about three years in advance.

A feeder bus plan was the focal point for the changes. About 40 percent of all RTD express routes were converted to local feeder bus operations. New bus schedules were developed using clockface headways and timed transfers at the LRT stations. RTD consciously decided on a strong truncation plan, but did not significantly adjust total bus hours, which declined by a nominal 0.1%. While feeder routes are shorter, the buses run all day in both directions, and some also run on Saturdays. Suburban routes with urban segments generally benefitted from the restructuring. For example, local service frequencies in Aurora increased to 15 minutes. From a service planning perspective, the Southeast area is more difficult to serve than areas previously covered by rail, with rapidly increasing population and lower density development relative to central Denver or the Southwest LRT line.

Most of the changes were effective and remain in place one year later. Only the "P" express line was restored. The service level declined in the immediate vicinity of the Civic Center (near the State Capitol and US Mint), because there is no LRT station nearby. Other concerns include increased out-of-direction travel compared with the more direct express routes, and the long-range costs of converting peak express routes to all-day feeder routes. First-year comparative ridership data has not yet been compiled; however, the results of the service changes are generally positive. The truncation plan concept was accepted politically before the changes were implemented.

LRT scheduling and runcutting are handled primarily by one Senior Service Planner/Scheduler, rather than as part of the team approach. With the opening of the Southeast corridor lines in November 2006, LRT became much more complex due to 2.5-minute spacing between trains on lines sharing a common alignment approaching downtown Denver from the south. Further adjustments are planned for the Southeast Corridor LRT line, including reduction of service and eventual discontinuation of the "G" line, and extension of station platforms to accommodate

Copyright National Academy of Sciences. All rights reserved.

four-car trains when 34 new rail cars are delivered within two years. Currently, most peak hour trains are three cars long.

Mall Shuttle

The 16th Street Mall Shuttle is a unique service with its own scheduling challenges. The shuttle is highly patronized with buses running every 75 seconds along a dedicated running way with signalized intersections at grade. Experience has shown that other frequencies do not work well, because buses generally need to operate between consecutive synchronized signals at 15-second intervals in order to maintain proper bus spacing. Past attempts to use different frequencies caused buses to miss signals and bunch up.

The Mall Shuttle operates with headway schedules rather than static schedules shown on run paddles. Starters (supervisors) are positioned at the Civic Center and Market Street terminals to dispatch buses as appropriate to accommodate demand. Once dispatched, the buses are regulated by traffic signal timing and cycle counters. Passenger boarding and alighting activity occurs at virtually every stop, and volumes are highly variable by time of day, and from trip to trip. RTD is moving away from the current mechanical wheelchair ramps installed on the buses to a manual ramp that will be quicker to deploy and retract as one means of removing schedule variability from Mall Shuttle operations. Scheduled recovery times of 3.75 minutes at Civic Center and 2.5 minutes at Union Station are planned

Mall Shuttle work assignments are cut separately from other bus work. Operators receive a 30-minute break per four hours of platform time, and up to two breaks per day assuming an eight-hour work day. The average actual time between breaks is about 3.5 hours. Meal breaks are packaged into two relief operator runs. No part-time operators are used in Mall Shuttle operations.

Technology Applications

Service Planning/Scheduling staff actively use and generally support the use of advanced technologies to facilitate and improve the scheduling process. Key technology components include Trapeze scheduling and Blockbuster runcutting software, automatic passenger counters (APCs) working in conjunction with Init's AVL/GPS system, and Ride Check Plus database management software. Ride Check Plus automates the entry, manipulation and reporting of ride check data from onboard surveys. Eighteen percent of the bus fleet currently is equipped with APCs. Staff preference is to eventually equip all buses with APCs.

RTD is relatively successful in its use of ITS technologies when compared with current industry experience. RTD staff has considerable experience with computerized runcutting, which was introduced in 1979 (Rucus) and transitioned to the Sage Minischeduler/Ramcutter in the 1980s and Trapeze/Blockbuster in 2004.

The APCs generate reliable data at the trip level and these data are electronically imported into the Ride Check Plus system. A contributing factor is that dedicated technical staff is assigned directly to the Service Development Division to maintain the computer systems. For example, an Applications Expert and a Support Technician report directly to the Manager or Service Development Support, who also oversees the service monitoring (i.e., traffic checker) group. A third support position recently was approved.

Copyright National Academy of Sciences. All rights reserved.

Staff believes that the current Windows-based version of Trapeze is somewhat of a weak link in the technology chain. Particular functions, such as route traces and integrated mapping capabilities have improved; however, the software reportedly runs slower than the older version of Trapeze run previously by RTD. Blockbuster works well, but only in four of 120 attempts did it yield a lower cost solution in side-by-side comparisons to the outdated Fortran-based Ramcutter. Runcut efficiency typically is measured in terms of annual cost, rather than pay-to-platform ratio.

Hiring, Training and Retention

Combining service planning and scheduling functions into teams in the early 1990s had a major effect on scheduling personnel. Current practice is to hire applicants with a college degree, using a written test developed by the current Manager of Planning & Scheduling, and administered by the Human Resources Department. The test includes a map reading element. The screening process also considers how candidates are likely to interface with the public

New hires attend a one-week Scheduling and Runcutting training course offered by the Canadian Urban Transport Association (CUTA), and gain apprentice training by working with veteran staff, presumably as the junior member of a three-member team. The last time a bus operator was hired into the Service Planning/Scheduling group was in 1994. Overall, the cross-fertilization of college-educated and traditional line employees at RTD has been beneficial.

The team concept provides a career progression for employees that did not exist when scheduling functioned as a separate unit. The team concept eliminated the entry level schedules clerk position. New hires typically start as a Planner/Scheduler I and test into the Planner/Scheduler II position after about five years of experience. Alternatively, an employee may receive a pay increase after five years without a promotion or changing jobs. This approach offers a logical career progression, eventually to Planner/Scheduler III. The teams were reduced to two members each for several years, but later were restored to three members. Staff preference would be to expand team size to four members.

It takes about four years to become a good scheduler. This period allows younger staff to go through several cycles of recurring tasks while associating with veteran staff. Leads are assigned to provide continuity. Staff occasionally shifts from team to team to broaden experience. The teams also may overlap or work together on larger projects.

Management generally is comfortable with departmental structure, staff capabilities and the qualifications of applicants. Still, recruiting is difficult to find the right set of skills to staff the unit. Recent hires have come from other public agencies, consulting firms, and one career change motivated by a particular interest in transit. Additionally, a retired RTD scheduler rejoined the group part-time after the Retirement Board removed restrictions on this practice. Other potential sources of qualified applicants include the airline industry and the military. Retention of experience personnel also is part of the overall staffing strategy.

RTD has a $125,000 annual contract with a consulting firm to provide supplemental scheduling and runcutting services as needed. However, the RTD Board is unlikely to accept large-scale outsourcing of service planning and scheduling activities.

Copyright National Academy of Sciences. All rights reserved.

E.7 StarMetro (Tallahassee, FL) Case Study

Introduction

StarMetro, known until recently as TalTran, operates the transit service in Tallahassee and on the campus of Florida State University. StarMetro schedules 54 buses on 34 routes at peak on weekdays and provide service seven days a week. The agency is typical of smaller transit systems where staff often has broad responsibilities over multiple functions. It currently schedules manually without a computerized scheduling program. However, an Intelligent Transportation Systems initiative is about to begin, which will create a host of downstream needs for computerized scheduling data.

Tallahassee's metropolitan area is home to a population of 356,000 (159,000 in the City of Tallahassee). Florida State University (FSU) currently has about 40,000 students, Florida A & M about 13,000 and Tallahassee Community College around 14,000. Sixty percent of riders on the system are students.

Normal hours of service are 6:30 AM to 7:00 PM on weekdays and 7:00 AM to 6:00 PM on Saturdays. On Sundays, nine of the routes operate 9:00 AM to 6:20 PM. Headways are generally 40 and 60 minutes. Six routes have 30 minute service during the AM and PM peak periods, which are 6:30 to 9:30 AM and 3:00 to 7:00 PM, and one route operates every 30 minutes all day. Two routes enjoy a 20 minute peak. Five predominantly campus oriented routes operate to 10:30 PM on weeknights. In StarMetro practice, most routes keep the same departure times (e.g., on the hour) and running times all day.

Bus requirements are as follows:

- Weekday peak – 54
- Weekday base – 49
- Saturday – 22
- Sunday – 9

A total of 96 operators are employed. Four of these are part-time. There are 11 extraboard positions, which represent about 11 percent of the full-time operator force.

In addition, StarMetro operates nine campus routes, serving FSU (7) and Florida A&M University (2 plus one shared with FSU). These routes operate from campus to outlying areas serving dormitories, other student housing, and retail and entertainment areas used by students. They do not go downtown. One route (the RE or Renegade) operates a campus-only loop on a 10-minute frequency. Four routes come into campus from outlying areas and operate around a similar loop (two in each direction). The routes are scheduled so that a 10-minute service is provided in each direction around the loop. The clockwise direction, which also features the 10 minute RE service, effectively provides a five-minute headway all day. There is also a night service route, which provides service every 45 minutes from 10 PM until 3 AM on Tuesday through Saturday nights. The service operates with three buses, providing 15-minute service to every point on the one way loop.

All of the "city" routes originate and terminate at a large off-street transit center, known as the C.K. Steele Plaza, or just "Plaza" for short. This terminal dates back to the 1980s and is scheduled for reconstruction and a revised layout. Currently, it is capable of accommodating 21

Copyright National Academy of Sciences. All rights reserved.

different buses at individual bays or "gates". The site of the terminal is approximated three blocks north of the center of downtown Tallahassee.

Fares at the time of this study were $1.25 for adults with free transfers. There is a day pass for $3 and a weekly pass for $10. University students ride free on the whole system with their student ID card which is paid by part of their student fee.

StarMetro is included as a case study as a system with fewer than 100 peak buses that still schedules manually. StarMetro has evolved from a pure radial system, with all routes meeting in downtown, to a mix of downtown and campus-oriented routes. Responsibility for the scheduling function is distributed among several staff members.

For this case study, the following people were interviewed:

- Ron Garrison – Executive Director
- Brad Sheffield – Director of Planning
- Samuel Scheib – Assistant Director of Planning
- Alphonso Menendez – Superintendent, Transit Operations
- Martha Martinez – Street Supervisor

The Scheduling Process

StarMetro does not have a dedicated scheduler position. Instead, several staff persons are involved with the scheduling process in addition to other primary responsibilities. The Transit Planning Administrator, Brad Sheffield, has responsibility for service planning and scheduling. Both Brad and his assistant, Sam Scheib, work on route design and prepare the operating schedule. The Operations Department, headed by Alphonso Menendez, has responsibility for the run-cut, adding pull out and in times and determining interlining patterns. The runcuts are normally done by one of his supervisors, whose primarily job is street supervision. The supervisor also finishes packaging the runs into rosters or "bid lines". StarMetro has six supervisors, most of whom are well-versed in runcutting and rostering.

Potential changes to the route structure and to individual route schedules start in the Planning Department. Planners use a bus to check out final route alignment and determine average running time by simulating normal bus operations and stopping at planned bus stops. Route lengths are designed to yield roundtrip running times close to 40 or 60 minutes. The roundtrip cycle is calculated and headway is determined for the route. Headways are set at a mathematical multiple of the roundtrip running time, usually with time for recovery at the downtown terminal. Layover and recovery is generally calculated five minutes or less at the Plaza.

Even though StarMetro's methods of scheduling and blocking are described as "manual," staff employs spreadsheets throughout the process, including the production of documents used by drivers for bidding and for performing their assignments (commonly called "paddles" in the industry). This is true at most properties that do not use a computerized scheduling software package. Even those agencies with scheduling software packages often use spreadsheets for ancillary tasks.

StarMetro holds three run picks a year. These occur at four month intervals. Supervisors handle the job of signing up operators. Supervisors also put together the runcuts and rosters. All work

Copyright National Academy of Sciences. All rights reserved.

to be picked is in rosters, which are made up of either four or five consecutive days of work totaling as near to 40 hours as possible for the week. Overtime is paid on a weekly rather than daily basis. Of the rosters, approximately 25 percent are made up of four day-10 hour runs. All work is accommodated in the roster with none left over as trippers or loose pieces. This is aided by the low peak to base ratio. Days off are consecutive, although the 4/10s may have the third day off separate from the other two.

Reliefs are handled by traveling in the agency's van to and from the relief point, which is usually the Plaza. Reliefs are grouped so that as many operators as possible can travel together and the number of vans required for reliefs is minimized. Fifteen minutes are allotted to the run for each travel to and from the Plaza. Times for travel to and from other relief points vary.

Some runs over eight hours in duration are given unpaid meal reliefs as close to the middle of the run as possible. These are covered by scheduling pieces of work that take care of multiple meal reliefs. These relief pieces form the first or second halves of split runs. Some unique scheduling of meals takes place on the FSU campus routes to avoid unnecessary travel. In some cases, runs are relieved in time to start these meal relief "strings", and then the driver will complete their assignment by relieving a regular run.

Scheduling Issues

Interlining

Some regular interlining of routes does occur at the Plaza, but the majority of buses stay on their own route all day. Interlining occurs between routes with the same headways and is designed to provide enough recovery time for reliable operation of the "route pair."

System Design

The route structure places the Plaza geographically close to the center of the system, which is ideal for scheduling purposes. And, as noted above, the route lengths yield round trip running times close to 40 or 60 minute mark. Since the headways of individual routes vary, there are buses arriving and leaving the Plaza at various times during the hour, which helps to avoid the heavy bus traffic that would occur if all buses were leaving at once.

Timed Transfers

While the system is not designed for timed transfers, StarMetro aims for five minute connection times between buses and schedules layovers at the Plaza to help facilitate convenient transfers in both directions. With varied headways, this is not possible to achieve for each trip.

Intertiming on Common Trunk Corridors

There is an effort made to schedule different routes in the same corridors on a staggered schedule. For example, on East Park Avenue, Routes 22 and 25 overlap for a considerable distance. One is scheduled to leave the Plaza at :10 after, while the other leaves at :40, providing a more convenient 30-minute headway to Governor's Square Mall. This occurs in other corridors as well.

Copyright National Academy of Sciences. All rights reserved.

Training

Scheduling training is best described as “on-the-job” and comes as part of the move up from bus operator to supervisor. Supervisors are expected to learn how runs are put together and be competent at compiling a sign-up. The “culture” has been passed down within the ranks of Transportation Division. The mix of city and university work and the meals on some of the runs complicates the runcut and makes it a challenge for a first time runcutting “student.” The craft is learned and improved upon over successive sign-ups.

New Technology

StarMetro has purchased fareboxes from a new supplier, Fare Concepts, a Canadian manufacturer. The fareboxes offer the new feature of built-in GPS, which allows the recording of fares by fare type at precise locations. This information will be linked up soon with automatic passenger counting equipment, an automated vehicle location system, and bus stop information displays. All of these items are part of a new Intelligent Transportation Systems initiative that has recently begun. The need to supply electronic data to these devices will require StarMetro to acquire a computerized scheduling and runcutting software package. Staff has begun preparing specifications for this package.

E.8 Ride-On (Montgomery County, MD) Case Study

Introduction

The County government in Montgomery County, Maryland began bus service in 1975, with some new routes and assumption of existing routes of the Washington Metropolitan Area Transit Authority (WMATA) in an area to the north and northeast of the District of Columbia. That system has grown to operate a fleet of 372 buses carrying about 90,000 passengers on an average weekday, or 29 million annually. The service is branded as “Ride On”.

System Description

Montgomery County, Maryland has a population of approximately 900,000 and is one of the most affluent counties in the nation. Major urban areas of the county include Silver Spring, Rockville and Gaithersburg. The route network stretches 26+ airline miles from the District of Columbia line to Urbana in the northwest, just across the Frederick County line, 22 miles to Damascus in the north and 15 miles from the Potomac to Burtonsville, near the Howard County line in the northeast. The area is served by both WMATA suburban buses (Metrobus), two legs of WMATA’s Metrorail Red Line (one to Shady Grove in the northwest and one to Glenmont to the north), Maryland MTA commuter rail and bus lines, and 80 Ride On bus routes. Ride On provides service seven days a week. Most Metrobus routes operate seven days a week as well, but some of its routes are given over to Ride On for operation on weekends.

Ride On is operated as a division of the Montgomery County Department of Public Works and Transportation. Approximately 67 percent of the service (in terms of peak buses) is operated directly by them, with operating personnel and management employed directly by the County. The remaining service (33 routes) is contracted out to private operators who use County-owned vehicles (vans and cutaways) and operate with schedules developed by Ride On’s scheduling staff. These are routes with lower passenger volumes that can be served by smaller vehicles with resultant lower operating costs. The costs, however, are rising as wages have increased to

Copyright National Academy of Sciences. All rights reserved.

keep the private operators competitive in attracting drivers. Thus, Ride On has served notice that it intends to discontinue the contracts. All service will then be operated by Ride On's employees.

General hours of service are 4:30 a.m. to midnight on weekdays and Saturdays and 5:30 a.m. to midnight on Sundays and holidays. Three buses stay out until 2:00 a.m., with the result that Ride On buses are on the street for a total of 22 hours per day. Headways range from a peak of four to five minutes to a base of every half hour. One route does operate every 60 minutes. Average peak headways are 15 minutes and average base intervals are 30 minutes. Ride On makes every attempt to schedule to a clockface headway, even though headways and running times vary during the day and a memory pattern leaving time is thus not possible at all points along the route.

Bus requirements are as follows:

- Weekday peak – 297
- Weekday base – 177
- Saturday – 164
- Sunday – 121

The above includes service operated in-house and contracted.

Ride On operates out of two garages, Gathersburg (108 buses) and Silver Spring (117 buses). A third facility is operated by the private contractor (currently MV Transportation), who fields another 76 vehicles.

A mix of 570 full time and 60 part time operators are employed. These employees are members of the County's MC-GEO labor union (Montgomery County Government Employees' Organization).

Fares at the time of this study were $1.25 for adults. There is a day pass for $3 and a bi-weekly pass for $10. Bus-to-bus transfers are free. Passengers can transfer at an additional charge (35¢) from Metrorail to Ride On.

Ride On is included in the case studies as an example of a number of transit systems that were brand new in the 1970s and have grown to become major systems today. Ride On is also an example of an agency that schedules manually with the assistance of internally developed computer programs that automate certain scheduling functions and outputs (described below).

The following people were interviewed for this case study:

- Howard Benn – Executive Director
- Philip McLaughlin – Manager, Operations Planning
- Chris Garnier – Transit Analyst (Scheduler)
- Carla Rivera – Transit Analyst (Scheduler)
- Deanna Archey – Planner

Phil McLaughlin is in charge of both the scheduling and service planning function and has three schedulers, one for each garage, and a Data Collection Supervisor. He is also involved in a number of the scheduling functions himself. If this were not so, it would be difficult to schedule

Copyright National Academy of Sciences. All rights reserved.

and runcut a system this large with such a small staff. He indicated that the staff is too small for the present workload.

The Scheduling Process

Scheduling at Ride On is best described as being done by hand with some computer assistance. Computers are used to print out the various documents used for operating, driver sign-up and other administrative functions. These include: bus block diagrams, run guides, driver manifests (paddles), headways, pull-out and pull-in sheets, and sign-up sheets. The programs that produce these documents were developed in-house by a talented individual who is no longer with the County. Ride On is in the process of procuring a dedicated scheduling and runcutting package from Trapeze. This package will receive thorough testing and parallel processing before becoming the primary method of producing schedules. The process, according to staff, is expected to take a year or more.

A number of the routes have all-day headways of 30 or 60 minutes or 15-minute peak/30–minute off peak. However, Ride On has its share of complicated schedules running on close headways. A prime example is Route 15, which serves an intense peak-demand corridor from Langley Park to Silver Spring Station on Metrorail. Headways in the AM peak are five minutes for a two hour period, before gradually widening to a 12-minute maximum for midday. There is a four-minute headway at the peak-of-the-peak which is sustained for a half-hour. These are certainly not simple schedules, as one might expect to find in a suburban setting.

Approximately 20 percent of Ride On's schedules are changed to some extent each year. The staff begins preparation for the changes a minimum of four months before the planned effective date of the schedules. Operations Planning staff meet every two weeks with an internal Service Monitoring Group committee, consisting of key Operations staff and driver appointees to discuss the needs and problems with the schedules. Staff uses this feedback to look at areas where overcrowding is occurring and where running time needs adjustment. It has also become the ideal time to proactively introduce Operations to upcoming plans for changes and adjustments.

Ride On conducts three sign-ups (called "picks" at Ride On) a year, every four months (January, May and September). Any of those picks can be used to make major changes in routes and service, although September is the preferred time for substantive changes.

Data on which to base changes comes from a traffic checking staff of 15 part-time personnel. Their primary duties are to collect data for federal reporting purposes and to ride check each route at least once per year for ridership and running time data. Ride On estimates an average of eight to ten routes receive running time adjustments each year and one or two more have their running times completely rebuilt using this data.

Ride On is in the process of acquiring 60 automatic passenger counters (APCs) sometime before the end of 2008. They will be based on Orbital technology and will be integrated with the AVL system.

Blocking is done on a standardized sheet showing arrival and departure times at major terminals. An additional bit of complexity comes from the provision for a meal break near the middle of a block that will be cut into an eventual run in the runcutting phase. This produces the case where blocking and runcutting become almost in integral task, as discussed in more detail below. The final blocks are printed out on Block Diagrams using a computer program developed in-house. The sheets show all trips, their routes and termini, and where the bus is parked for

Copyright National Academy of Sciences. All rights reserved.

meal breaks against a time-based grid. The sheets are provided in the headway book as a handy reference when checking on the scheduled location of a particular bus.

Runcutting and rostering are performed completely by hand using time-honored large sheets of paper familiar to veteran schedulers. Runcutting is an iterative process, where the block make-up is considered and trips are shifted onto or off the block in order to make the size of the run work properly. This method requires intense concentration and attention to detail and is aided by paper or ceramic boards where it is possible to keep track of all the available pieces. But it also produces the most efficient mix of blocks and runs.

All straight runs contain an unpaid break for meals somewhere near the middle of the run. Normally, the operator parks the bus at the transit center or rail station and takes between a 37 and 60 minute break. During that time, other blocks continue to provide the service on each of the routes. This iterative process (combining blocking with runcutting) provides the most cost effective runs, but also takes longer to put together because of the sheer number of trips that have to be considered.

Finished runs are rostered into Pick Sheets, which contain the five days of work and two consecutive days off. Ride On also has some four day/10 hour shifts. Part time work is also rostered. Part time runs at Ride On consist of three to five hours of work over five days, with consecutive days off. Part time assignments are all one piece with no splits.

Scheduling Issues

Interlining

Ride On is unique in its attention to maximizing route interlining. All routes have at least one terminus at a transit center or Metrorail station. Schedulers early on looked for patterns of roundtrip cycles on routes at each of these termini where interlining would link long routes that are tight for time with shorter routes where layover is more than adequate. In many cases a more complex interlining pattern was established, featuring three or more routes. Another purpose of interlining was to take any monotony out of the driving day and to give operators as much diversity and knowledge of multiple routes as was practical.

In addition to creating a more varied work day, the interlining scheme also saves money. Interlines are created by hooking routes together at transit centers on a “first in first out” basis. Savings are accrued by “hooking” each arriving trip to the next trip out, regardless of line, provided that the vehicle types are consistent and recovery time is adequate. To quantify the extent of potential savings, a blocking study of the Silver Spring garage was conducted a few years ago with all buses hooking back to their own routes. This produced a six percent increase in hours over the then-current schedule and also required seven additional peak buses. A similar saving from interlining Gaithersburg routes was estimated. The result confirmed that scheduling staff was on the right track with the interlining methods employed.

Downstream Applications

In addition to the normal scheduling tasks, the staff is also responsible for a moderate amount of downstream activity. This includes production of public timetables, individual bus stop schedules, telephone information materials, and (within a year) feeding data to an automatic vehicle location system.

Copyright National Academy of Sciences. All rights reserved.

Scheduler Training

The Ride On Operations Planning Department has experienced moderate turn-over in scheduling personnel in the past ten years. Training is a combination of passing down the craft largely through classroom work and a lot of time spent working on schedules under the watchful eye of seasoned schedulers. The incumbent schedulers are young, but have been with the system for several years and have been indoctrinated into the Ride On way of scheduling, blocking and runcutting. The normal progression path to scheduling is from the driver ranks. Most of the people promoted into Scheduling have been temporarily assigned there previously and their skills at scheduling have been assessed prior to considering them for promotion.

The Manager of Operations Planning has been with the system for over eight years and carries the historical perspective (corporate memory) from his predecessor. He believes that the workload should get a bit easier with Trapeze, since it handles the data between the various scheduling tasks and can pass on the data to the downstream applications without having to re-enter much of it.

What will not change is the need to manually intervene in the process of building blocks and constructing runs. Ride On has specified the Blockbuster© optimizing runcutting module for Trapeze, but this module has only recently added a routine for interactively blocking and runcutting and this system's requirements will surely test the viability of that routine. At this point in time, Trapeze does not provide a heuristic blocking routine that can be used to perform a systemwide or garage-wide optimization of all trips into blocks. Much of the blocking strategy will continue to require manual development.

E.9 Capital Area Transportation Authority (Lansing, MI) Case Study

Introduction

The Capital Area Transportation Authority (CATA) provides transit service in Lansing, MI and the surrounding area. Lansing is the capital of Michigan and home of Michigan State University (MSU). CATA operates 78 peak buses from a single depot and employs 153 full-time and 46 part-time bus operators. The Lansing portion of the CATA network operates on a pulse system with timed connections downtown at the CATA Transportation Center. All scheduling work is done by the Service Planning Manager, with input from others. The Service Planning Manager reports to the Assistant Executive Director.

CATA is included in the case studies because it provides a good example of the scheduling process at a transit agency with fewer than 100 peak buses. CATA utilizes a computerized scheduling software package (Trapeze), but relies on a mix of manual and computerized processes to produce its schedules, runcuts, blocks, and rosters. As is the case at many small transit agencies, one person is responsible for all scheduling and service planning tasks.

Three individuals were interviewed for this case study:

- H. James Froehlich, Service Planning Manager
- Sandy Draggoo, CEO/Executive Director
- Debbie Alexander, Assistant Executive Director

Copyright National Academy of Sciences. All rights reserved.

The Scheduling Process

CATA uses a combination of manual and computer processes to complete their scheduling tasks. While one individual is responsible for completing all of the technical scheduling tasks, there are a number of places for input by a wide variety of stakeholders including bus operators, the public and the Board of Directors. The following is the process followed by CATA, leading up to a schedule revision and "pick" by operators.

1. *Service Review Committee input*. CATA has an internal service review committee that identifies service levels for new routes and for route changes. The committee responds to direction provided by the Board of Directors, which annually sets target service levels for the coming five years. CATA management and staff make the decisions on where service should be increased or decreased, with the Board's approval.

2. *Running times*. Select bus operators designated by the union, Operations Department Staff and the Service Planning Manager drive proposed new routes with a bus, simulating stops, to estimate running times. This step is also undertaken for any routes with an identified scheduling issue. CATA has recently implemented different running times by time period. Off-school periods and state holidays are also important factors affecting running time. CATA serves many middle school and high school students, and trips at 3 p.m. that operate past schools usually fall behind schedule due to heavy loads. While some running time differential may be provided for these trips, enough recovery is provided to allow them time to recover on their next trip. CATA is located in a region subject to frequent heavy snowstorms, but schedules are not developed for snow days. In the event of heavy snow, service is coordinated to allow the last scheduled trip to depart on time. Overall, establishing running times is a function of route length, pulsing requirements, and union input. CATA uses APC data to confirm running times on individual segments.

3. *Field check*. The Service Planning Manager drives the route in a van to note any potential problems with stop placement, pedestrian activity at major trip generators, turns, or other issues and to identify any routing alternatives to address problems.

4. *Mapping*. The Service Planning Manager maps the route in Trapeze. CATA utilizes a base map that provides accurate geocoding information for stop locations from the State of Michigan.

5. *Trip patterns*. The Service Planning Manager identifies any alternate patterns for short-turns or branches and codes them at this stage.

6. *Span of service*. Once routing and running times are determined, the span of service is finalized. Most routes in the CATA system operate between 6 a.m. and 11 p.m., with the last departure from downtown at 10:15 p.m. Route 1, the major route serving downtown, MSU, and Meridian Mall east of campus, operates later on Friday and Saturday nights during the school year. A paratransit vehicle operates on campus between 2 and 7 a.m., thus providing 24-hour service. Most routes operate seven days a week, with a less extensive service span on Saturday and Sunday.

7. *Building the schedule*. The Service Planning Manager lists all trips and timepoints by direction. This is done in Trapeze. Most local routes operate at headways of 30 or 60 minutes during the day. CATA does not have a contractual requirement or standard for

Copyright National Academy of Sciences. All rights reserved.

8. *Blocking*. The Service Planning Manager usually blocks the trips electronically making final adjustments manually.

9. *Runcutting*. Because the service is not changing dramatically, most runs can be built simply by replacing existing work pieces with similar new pieces. Therefore, the runcut is typically a manual process at CATA. In a system of this size, there are opportunities to customize the runcut to generate efficiencies. The Service Planning Manager looks for "dangling" trips to interline, also considers options to adjust layover and recovery time to maximize efficiency on a trip by trip basis, particularly when headways transition. CATA evaluates its runcuts in terms of pay to platform ratio. Currently, this ratio is 1.1, leaving very little room for increased efficiency through a computerized runcut.

10. *Rostering*. The final step of the process is to prepare a roster. Work assignments and days off are prepared by CATA. Every attempt is made to create work pieces that have either identical runs every day or runs that operate the same line. As more work is rostered, the ability to do this diminishes. For each sign up, there is Union review of the paddles and roster. Final adjustments are made in the roster at that time before posting. Consecutive days off are guaranteed only for operators who work both Saturday AND Sunday.

11. *Implementation*. CATA has a service change implementation team composed of representatives from marketing, maintenance, operations, and facilities. The team meets monthly, as needed. Its goal is to coordinate service change events to ensure that customers are optimally served. Supervisors and dispatchers are informed of service changes well in advance of implementation so that they have the chance to ask questions and clarify anything they do not understand.

Scheduling Issues

System Design

The CATA system is designed as a pulse system, with timed connections in downtown Lansing at the CATA Transportation Center (CTC). Making time transfers work is a critical factor in schedule design. Buses are held for up to five minutes at the CTC or at other timed transfer locations to ensure that transfers can be made. Interlining key routes (discussed below) is one way to ensure that the pulse system does work.

As time passes, routes are increasingly designed to operate on arterial streets and are less likely to penetrate into neighborhoods where safety issues with parked cars and children are a concern. This is especially true in the design of new routes. It is also true, however, that people buy houses based on the proximity of bus service in the neighborhood. As a result, older routes are not likely to be changed to take them out of neighborhoods.

University Service

Michigan State University is a major focus of the CATA system. MSU formerly operated its own campus shuttles, but CATA now operates these under an agreement with the university.

Copyright National Academy of Sciences. All rights reserved.

Published timetables delineate certain trips as “Spartan service trips” that operate only when MSU is in session. Late trips on Route 1 on weekends are an example of trips that operate only when the University is in session. On Route 25, which also serves the campus, headways are 20 minutes when MSU is in session and 40 minutes at other times.

There are several problems in planning campus services. Service demands vary dramatically during the service day. Service also fluctuates between service days. For example, CATA operates a reduced schedule on Friday of each school week. Finally, MSU does all road repairs on campus during the summer, which often has unexpected impacts on routing and running times in the campus area, and can impact “time checks” for fall services.

Interlining

CATA has used creative approaches to interlining to ensure that critical connections are made and to maximize one seat rides for key markets. For example, CATA recently started a new route from Downtown to North Lansing. This route is interlined on the downtown end with a route from South Lansing, and on the North Lansing end with a route to MSU, thus ensuring that critical transfer connections can be made.

Interlining can result in delays from one route spilling over to affect another. CATA has not had issues with delays caused by interlines. Routes with rail road crossings that are subject to delays would be a factor, but these routes are operated as stand-alone routes and are not interlined.

CATA also tends to interline routes with ample running and recovery time with routes that are scheduled more tightly to balance out an operator’s workload. This practice is designed to avoid the domino effect of increasingly late departures throughout the day on routes with tight running times. However, this does not always work as planned. For the August 2007 pick, CATA interlined three routes on the MSU campus to save a bus, but the union complained to the CEO that the running times were too tight. CATA adjusted the running times as quickly as possible.

Swing Shifts

CATA has two kinds of split shifts: (1) regular splits, which are limited to a maximum of 2.5 hours swing time; (2) wide splits, which have no swing limitation, but are limited to seven per pick. Although not required, attention is given to keep the spread time to as close to 12 hours as possible. CATA is careful not to roster a mixture of straights, regular splits, and wide splits, giving senior operators the best chance at the kind of route they want to pick. Any break in excess of 2.5 hours is paid as overtime. There can be only one unpaid break in a shift.

Meal Breaks

Meal breaks are created by: (1) a service fall-back (i.e. the line shuts down for 30 minutes); (2) breaks cut in the blocks (requiring an added bus to cover lunch reliefs); and (3) breaks cut in the run cut. This works when the lunch break time is equal to the running time of the route.

Extraboard

CATA’s formula for sizing the extraboard is approximately 12 percent of the number of rosters.

Copyright National Academy of Sciences. All rights reserved.

Labor Relations

The CEO has an open-door policy with the union, and values a positive relationship. The head of the union accompanied the CEO to accept the APTA award for best small system this past year. The union can use this open door as a vehicle to complain about schedules separate from the standard scheduling process. When complaints come directly to the CEO, she discusses the complaint with the Service Planning Manager and encourages him to work out a solution.

The bus operators' union designates three operators to work with CATA on scheduling issues. The operators know that they can bring scheduling and running time issues to one of the three designated operators. The CEO's perspective is that the union has to feel that the core of full-time runs will always be there, and understand the balancing involved in scheduling. She fosters the union's core belief that this is their system, which in turn keeps work standards high

CATA recognizes the tradeoff between efficiency and operator burnout. The contract requires eight hours off between shifts, but CATA avoids a 5 a.m. report time one day followed by a 2:30 p.m. report time the next day. Whenever possible, each operator gets the same type of work. Late night campus service can make this challenging.

Part-Time Operators

The union contract limits the number of part-time operators to no more than 32 percent of the work force. Part-time operators are allowed to work up to 30 hours per week. CATA keeps part-time assignments between 25 and 30 hours per week, and generally avoids a part-time roster with anything less than a four-hour daily assignment.

Automated Passenger Counters (APCs)

CATA has APCs on 15 of its buses (peak pullout is 78 buses). The buses are rotated throughout the system to survey each route every two weeks. Historically, buses have been assigned to specific runs – an operator would drive the same bus every day – and this complicates the APC assignments. Load data from the APCs are not useful, because loads accumulate through the ends of trips during the day. Boarding and alighting data are very useful, as is running time data between specific timepoints.

Computerized Scheduling

CATA uses Trapeze for scheduling, but does a mix of computerized and manual work. CATA uses Trapeze for stop-specific information and for scheduling functions other than runcutting. The Service Planning Manager views scheduling as a highly visceral skill and thus does most runcutting manually.

CATA is currently upgrading to the latest version of Trapeze, which includes Blockbuster. This module provides robust blocking and runcutting capabilities.

Downstream Requirements

Downstream Trapeze systems include Infocom (customer information), Infoagent, and Infoweb. Infocom documents customer input (compliments, complaints, and service requests), while the other systems enable trip planning, either with the help of a customer service representative or

Copyright National Academy of Sciences. All rights reserved.

on-line. The OPS package makes all the computerized scheduling data accessible to Operations, and also includes time and payroll functions. The next step in OPS implementation is an electronic bidding process. One strength of computerized scheduling is facilitating the transfer of schedule information to the downstream systems.

Senior Management's Perspective on Scheduling

CATA's CEO values a non-adversarial process to resolving scheduling issues. Senior management recognizes the importance of scheduling and delegates a high degree of autonomy to the Service Planning Manager to manage the scheduling process.

In the industry as a whole, the extent to which general managers understand scheduling depends on how they came through the ranks, the size of the system, and whether they have strong ties with operations. At CATA, senior management is aware that scheduling issues are sometimes personnel issues. As an example, high-seniority operators on Route 1 (CATA's busiest route) run the schedule perfectly, but other less experienced drivers find they cannot keep to schedule. Supervisors are needed in the field to keep the junior drivers on schedule, but the union also has to take a role in helping to train the new drivers to operate the route correctly. After a new driver picks his/her first work assignment at CATA, a senior operator will ride with the new operator on his/her route and fills out a daily observation report.

Scheduling is a critical component of an Information Technology strategy at CATA. Scheduling connects to operations, payroll, APCs, the ridership database, customer service, and web development. The ridership database is developed from GFI data analyzed through a series of filters. Automated Vehicle Locators (AVL) and Mobile Data Terminals (MDT) are being implemented, and these also tie in to schedules.

CATA's future vision is for completely electronic schedules, with no need for printed timetables. CATA is redesigning its website to include trip planning, real-time bus information, and text messaging to those who have signed up to receive information for a specific route. When the technology comes on line, there will be even more need to integrate schedules data throughout the system.

Senior management identified several challenges with regard to scheduling:

1. *University service*. Frequencies have to be so intense, but student class times drive demand. How do we reconcile these to provide service when it is needed?

2. *AVL*. Implementation of the new AVL system will provide new opportunities for how CATA schedules and how it monitors schedule adherence. Is CATA positioned to take advantage of these opportunities?

3. *Peak capacity problems* throughout the system. The weather and daily changes in demand contribute to these problems. How can CATA find out where these problems are likely to occur before they happen?

4. *Flexibility*. How will the implementation of new technologies allow CATA to do things in a different way for a different purpose, with greater flexibility? Scheduling tends to be inflexible because of the way the agency needs to communicate with its customers today. As the means of communication change in the future, will the scheduling process change also?

Copyright National Academy of Sciences. All rights reserved.

CATA's senior management expressed confidence in its current scheduling procedures and generally takes a hands-off approach to scheduling. As ITS implementation continues, senior management can envision changes in the scheduling process toward greater flexibility and short-term responsiveness.

E.10 Metro (St. Louis, MO) Case Study

Introduction

Metro is the regional transit system serving the City and County of St. Louis, Missouri and Monroe and St. Clair Counties in Illinois. Its legal name is still the Bi-State Development Agency, but Metro is the branded name which is marketed to the public and carried on all vehicles and graphics. The agency was formed by an interstate compact dating back to 1949. It became an operating transit agency in 1963 when it took over the routes of St. Louis Public Service and 15 other private carriers on both sides of the Mississippi to provide transit in a four county area in Missouri and Illinois.

Metro presently operates a fleet of 395 buses out of three garages (two in Missouri and one in Illinois), plus an interstate light rail line (MetroLink) consisting of two routes operating out of two facilities and covering 46 miles. The bus system consists of 79 routes. Together, the system carried 54 million riders in the last fiscal year. The entire system is operated by Metro staff, with no contract operation.

Metro uses Trapeze FX software for headway generation and blocking, and Blockbuster for runcutting. Much of the scheduling staff has been working in scheduling for many years and is well versed in both manual and automated scheduling techniques.

Principal contact for this interview was Todd Plesko. Todd heads an operational planning organization which includes service planning, scheduling and data collection and which reports to Operations. Interviews were conducted with four persons, including:

- Todd Plesko, Chief, Planning and System Development
- Lance Peterson, Director of Service Planning
- Tyagarajan ("T") Srinivas, Director of Scheduling
- Andy Sisk, Transit Services Manager

Metro offers an example of scheduling skills that have been passed down from the private enterprise days to the present. There has been ample opportunity to learn over the past 15 years from building entirely new schedules in support of major route changes. During that time, Metro has steadily converted from a traditional radial and crosstown bus system to one with a significant amount of routes that have become feeder to MetroLink as the backbone of the system.

The Bus Scheduling Process

Metro currently schedules 322 buses during peak hours and 223 buses during midday hours. The peak-to-base ratio is 1.44, which is relatively low for a large urban system but indicative of the role that rail plays in the passenger mix. Most routes are scheduled on clockface headways, with timed transfers occurring at MetroLink LRT stations and suburban bus transfer stations.

Copyright National Academy of Sciences. All rights reserved.

Maintaining consistent headways in light of changes in running times is a challenge for schedulers.

Trapeze FX is used to build bus schedules and blocks. The information is stored in a SQL Server database which provides standardized reports, such as headways and paddles. Metro has long made use of interlining to save equipment where possible. Interline candidates are developed by hand.

There is a division of responsibility in scheduling trips. The senior staff, all of whom are managers, build schedules and develop initial blocking solutions. Draft headways are turned over to the unionized schedule makers for adjustments as necessary to meet recovery goals and to prepare for runcut. The contract requires a minimum five minute recovery at the end of each trip, but with frequent requirements to meet connection times at rail stations and outlying transit centers, this is usually exceeded. The average layover/recovery is around 15 percent.

Runcutting is straightforward, but is constrained by what the scheduling staff considers to be very restrictive work rules. Metro does not provide meal reliefs as such. Meal breaks can be taken during longer layovers, which may be built into the schedule for connection purposes or to help achieve a clockface headway. The Director of Scheduling has adjusted the work rules within Blockbuster to obtain optimum results on a garage-by-garage basis. The summer 2007 runcut at one garage had a pay-to-platform ratio of 1.11, which is well within the range expected on a property without meal reliefs.

The use of part time operators is allowed and Metro makes use of them, primarily in weekend work. The contract allows for seven percent part time.

The schedule makers also figure prominently in preparing the finished data for downstream distribution to the myriad departments that are dependent on updated schedule information. Schedules information is critical to the operation of Metro's automated information call centers, GIS mapping systems, automated vehicle locator (AVL) and automated passenger counting (APC) systems as well as on-board next stop announcement hardware.

Scheduling Issues

Interlining

Metro does have a contractual limitation on the maximum number of interlines that can occur in each run. While this provides operators consistency throughout their day, scheduling staff views this as a limitation to gaining further system scheduling efficiency.

Runcutting

As noted above, Metro schedulers work within the confines of fairly restrictive work rules in cutting runs. Sixty-five percent of weekday runs are required to be straight. That percentage increases to 85 percent on weekends. Splits must be completed within a spread of 12.5 hours. Spread penalties occur after 11.5 hours (11.0 on rail) and reach a penalty of an additional straight time after 12 hours. Another complication is that a certain number of the all day blocks on each line must contain an early straight run. There are also restrictions on the amount of platform time in runs and on the number of trippers that may be left after all work has been made into productive runs. Discussion with staff indicated they have not been included to any

Copyright National Academy of Sciences. All rights reserved.

meaningful extent in labor negotiations, where some relief for these restrictions would increase the productivity of the schedules.

Scheduling Training

Metro offers an example of scheduling skills that have been passed down from the private enterprise days to the present. The system's schedule manager has extensive scheduling experience. Newer managers bring private sector expertise in computer systems and training. The entire system has been rebuilt and new schedules created over the past 15 years, providing ample opportunity to gain proficiency with Trapeze. During that time, Metro has steadily converted from a traditional radial and crosstown bus system to one with a significant number of routes that have become feeder to MetroLink as the backbone of the system.

Ridership Data

Metro has a fleet that is almost entirely equipped with automatic passenger counters and automatic vehicle location. These items have facilitated data gathering for new schedules. Staff takes on the task of eliminating data that does not conform to norms, including incomplete trips or other kinds of "outliers".

Rail Scheduling

Rail scheduling is not yet fully automated and is performed using spreadsheets at present. The manual functions in the Trapeze program are utilized, allowing Trapeze to format and print reports and maintain statistics, even though the software is not utilized for optimization.

The rail operating schedule is complex in that it includes every station as a timepoint. That yields 39 timepoints in each direction. Two services are operated: the "mainline" Airport to Shiloh-Scott AFB and the year-old Cross County line from Shrewsbury to Emerson Park, a midway station with a pocket track on the east side of the mainline. The two services are scheduled with evenly spaced headways along the common portion of both routes to give double the frequency along their common segment. During peaks, that results in a train every five minutes, with 7-8 minute midday headways. All trips are operated with two-car trains of articulated LRVs seating 72, with a standing capacity set at 100. Metro has 87 such vehicles and schedules 56 (28 trains) at peak, 38 (19 trains) at midday and on weekdays.

Staff is looking at the possibility of separately adjusting the amount of service operated on each route, which would result in uneven headways on the common segment but would better respond to demand on each independent line. In addition there is a desire to extend the short line from its current terminus at Emerson Park two stops east to Washington Park, so that the busy Jackie Joyner-Kersee Center station would have more trips passing through. To accomplish this, a pocket track is needed at Washington Park to provide for trains laying over.

Runcuts are performed using the manual runcutting routines within FX. This allows the program to keep track of the statistics and to issue Run guides and other output documents using standard Trapeze forms. One complication with the runcut comes from the need to get train operators back to their respective yards at the end of the shifts while attempting to minimize travel time payment.

Unlike other rail systems included in the case studies, MetroLink does not use fallback scheduling of operators at end terminals at this time, which saves one step in blocking service.

Copyright National Academy of Sciences. All rights reserved.

Similar to the bus system, all rail runs are rostered with days off assigned. Yard jobs are included as part of the rosters.

E.11 Capital District Transportation Authority (Albany, NY) Case Study

Introduction

The Capital District Transportation Authority (CDTA) is a regional transportation agency serving a four-county area around Albany, NY. The four counties are Albany, Schenectady, Rensselaer and Saratoga. Besides Albany (population 94,000), the major cities in the area include Schenectady (population 62,000), Troy (48,000), Saratoga Springs (27,000) and Rensselaer (population 7,800). The population of the urbanized area is 734,000. CDTA was formed in 1970 and took over operations from private operators in 1971-2. The largest private operator was United Traction Company, who had provided the streetcar and bus service in Albany since the early 1900s.

System Description

CDTA operates a fleet of 234 full size buses operating out of three garages. Garages are located in Albany (113 buses), Troy (56 buses) and Schenectady (50 buses). In addition to the fixed route fleet, there is a fleet of around 25 small buses and vans providing paratransit for the same service area.

These buses operate on 58 routes, which include mainline local and limited stop, park & ride, and suburban shuttles. The routes cover an area of 150 square miles. Service is operated for about 20 hours a day on weekdays and Saturdays and about 12 hours on Sunday on 21 of the routes. Headways range from 15 to 65 minutes in the base and 10 to 30 in the peak. The best route on the system in terms of overall service is the 22-Albany-Troy-Rensselaer (10 peak, 15 base), followed by 55 Albany-Schenectady via Central Avenue (15 peak, 20 base). The latter corridor is slated for upgrade to a Bus Rapid Transit route during 2008.

Current weekday system boardings exceed 42,000. CDTA reports that the top six routes carry 50 percent of the ridership and 75 percent are on 16 of the 48 routes. Not surprisingly, these 16 are the trunk routes in the most urbanized areas of the region.

CDTA also operates several circulators, including an Albany route that circles the state office campus and a summer-only route in Saratoga Springs. These use smaller buses or trolley replicas. CDTA also operates shuttles on the SUNY Albany campus and at Rensselaer Polytechnic Institute in Troy.

Uniquely, CDTA owns and operates two railroad stations devoted to regional and long distance passenger service. The station in Rensselaer, designed and partially funded by CDTA, is a major Amtrak hub and also serves as an office complex for CDTA. The other station is in Saratoga Springs, serving Amtrak's daily New York – Montreal "Adirondack."

Bus requirements are as follows:

Copyright National Academy of Sciences. All rights reserved.

- Weekday peak – 185
- Weekday base – 115
- Saturday – 73
- Sunday – 36

CDTA operates all of its own service, with the exception of Northway Express (NX) commuter trips, which are operated under contract by Upstate Transit, the former owner of the routes. CDTA supplies 12 MCI buses to Northway for this service. NX connects the State office campus with areas in Saratoga County and provides directional peak service on weekdays.

At present, CDTA budgets for 345 bus operators, all of whom are full time. As with other systems, the actual number available is usually lower than the budgeted figure due to attrition and the time it is taking to recruit and train new operators. Part time positions have all been eliminated as this particular work group proved difficult to recruit and retain. CDTA's operators, supervisory staff and some middle management are members of the Amalgamated Transit Union.

CDTA changed their fare structure in 2005 in a move to simplify fares and eliminate transfer abuse. On all local routes, the fare is $1. Use of transfers was discontinued, replaced by a day pass for $3. Revenue has increased and the fare structure change has been credited as one factor in increased ridership. The NX service is not part of this structure, having a traditional commuter style, mileage-based zone fare with an emphasis on discounted monthly passes.

The following people were interviewed for this case study:

- Kristina Younger – Director of Strategic Planning
- Anthony Grieco – Director of Service Planning (since retired)
- Bill Redden – Manager of Service Planning (Chief Scheduler)
- Michele Gaudet - Scheduler
- Thomas Guggisberg – Director of Information Technology
- Christopher Desany – Chief Information Officer

Kristina Younger is in charge of both the strategic and long range planning functions. She reports to the Deputy Executive Director of Business Development, one of four direct reports to the Executive Director. Strategic Planning and Service Planning are on the same level, but the functions of both are intertwined at present, with Strategic Planning having the charge to rethink how service is branded and delivered. The resulting strategic plan describes in detail the annual service review process, which is central to all route and service changes.

The service planning and scheduling functions are carried out by the same people at CDTA, although the scheduler spends most of her time on scheduling and review of ridership data.

The Scheduling Process

CDTA has used the Hastus software package from Giro for about eight years. There is still some scheduling done with pencil and paper, as appropriate to get a quick view of how a schedule will work, before feeding the information into Hastus and completing the job electronically.

Copyright National Academy of Sciences. All rights reserved.

The practice of scheduling has been handed down at CDTA from the “old hands” of the United Traction era. There has been a steady succession of long-term employees in scheduling who could pass down the corporate memory, and this continues today.

Schedules are kept relatively simple. Routes are straightforward, generally lacking a large number of “patterns”, such as turnbacks, branches and alternate routings. In fact, CDTA’s policy is to limit the number of patterns for each route type, with no more than two patterns on trunk local routes. Use of clockface headways is emphasized to the extent that they are feasible. An appropriate round trip cycle is worked out for each of the major time periods of the day. In that sense, schedules are built to allow for efficient blocking. However, CDTA still blocks by garage once all of the schedule work is complete. This effort searches for potential interline opportunities which can save buses during the peaks and periods before and after. Even with clockface as a goal, there is a diversity of headways. As an example, most suburban routes run every 25 to 50 minutes. Because of this diversity of service frequency, there is relatively little opportunity to schedule meets at outlying transit centers.

Ridership and running time data comes from both AVL and APC systems. As of this writing, 48 buses in the fleet are equipped with APCs and all new buses received have them, so eventually the entire fleet will be equipped. CDTA has a cadre of up to six traffic checkers, who mostly work on specialized checks such as for National Transit Database reports. When a large check is needed, CDTA can also field supervisors and Travel Trainers. Ridechecks to obtain data for running time revisions are done as needed rather than on a set schedule.

The contract with the Amalgamated Transit Union requires three schedule sign-ups a year. These are timed around the school out, school in and end of year time frames.

CDTA makes complete use of the optimizing CrewOpt module in Hastus to cut driver runs. Each garage is cut as a unit, using all blocks scheduled at that garage. Staff believes that this produces the most efficient set of runs. From time to time, a subset of the runs for each garage is frozen from the previous runcut and the remaining work is optimized around them. This is done when there is relatively little change in the blocks.

As with the schedules, the runcut at CDTA is relatively simple and straightforward. The contract requires a minimum of 60 percent of weekday runs to be straight. The system does not schedule meal breaks in the runcut. There is no provision for four day/10 hour runs. The peak-to-base-ratio of 1.6 is not onerous in terms of allowing for a runcut solution free of a lot of leftover pieces. At present the number of trippers is: 8 a.m. and 10 p.m. in Albany, 5 a.m. and 7 p.m. in Troy, and 4 a.m. and 4 p.m. in Schenectady.

Sign-ups are cafeteria style. Schedulers do not roster any of the work, but allow the operators to choose their days off separately from their work.

Scheduling Issues

Business Process Re-engineering

CDTA’s IT department has become involved in sign-ups to a greater extent than in the past by developing a six page flow chart of all the tasks that have to be accomplished for each service change. The chart includes Service Planning and computer system tasks as well as those of Scheduling. IT’s primary concern is typical of many transit systems in this age of heavy downstream uses of electronic information. Data flow encompasses the AVL system, growing

Copyright National Academy of Sciences. All rights reserved.

APC use, website information based on schedules, and additional on-board requirements such as correct settings for the electronic registering fareboxes. Therefore, assuring that scheduling and run data is correct as early in the sign-up process as practical satisfies one of IT's major ongoing projects. At CDTA, IT has taken the role of partner with the schedulers in producing sign-ups.

Rebranding

In 2005 the agency completed a comprehensive assessment of the services operated by CDTA. The result was the Regional Transit Development Plan, which was finalized in January 2007. Of interest to schedulers are some of the following items produced as a result of this study.

- *Transit Propensity Index*
  This combines several population characteristics, such as population density, percent above or below certain age levels, zero car households, and such with attractions for transit riders, such as shopping centers and colleges. This can be used to identify potential new areas for bus service and the likelihood for success in attracting ridership.

- *Service Design Principles*
  The system's service standards have been derived from this, including such elements as span of service, route spacing, and service frequency.

- *Systematic Fleet Replacement Plan*
  While this is a highly desirable planning tool for the whole agency, the scheduler benefits from discussion about bus types and sizes. For example, CDTA is considering articulated buses for future use on the BRT service. The agency once had a small fleet of articulated buses, but the particular model did not perform well in ice and snow. The Maintenance staff is now ready to look at articulated buses again for the BRT corridors.

In addition, the study also resulted in a new image for the system and the bus fleet, including a rebranding of the service, which is now known as the "iBus". Along with this was a change in the design of the public timetables which feature the use of color and heavier paper stock, making them more attractive and, hopefully, giving clearer information to potential patrons.

E.12 MTA-New York City Transit Case Study

Introduction

MTA-New York City Transit (NYCT) is by far the largest transit agency in the United States, operating 3,866 peak buses out of 18 depots (two more depots will come on line in 2008) along with a fleet of 5,800 subway cars. The Scheduling Department has a total of 70 schedulers, with half assigned to heavy rail and half assigned to buses. The Scheduling Department is part of the Division of Operations Planning.

While the sheer size of this agency might suggest that it does not share experiences with most other transit operators, NYCT's schedules are developed at the depot level, with depots ranging in size from 100 to 300 buses. At this level, the scheduling process is very similar to scheduling at a medium-sized transit agency. There are obviously complexities related to the sheer size of the NYCT system and the frequency of bus service. As a case study, NYCT offers extensive experience with computerized scheduling, innovative scheduling practices, and very different budget environments over a relatively short period of time. NYCT uses Hastus as its automated

Copyright National Academy of Sciences. All rights reserved.

scheduling system, and has added functionality to its computerized scheduling over a number of years. The system has a close relationship with Giro, the Hastus developers, and many of the enhancements in the Hastus system are a result of this on-going partnership.

Five individuals were interviewed for this case study:

- Michael Glikin, Senior Director, Bus Schedules
- Michael Chubak, Executive Vice President
- Joseph J. Smith, Senior Vice President, Department of Buses
- P. J. Diskin, Deputy Director, Bus Schedules
- Steven Viglietta, Senior Manager, Hastus Implementation, Bus Schedules

The information presented in this case study relate primarily to bus scheduling at NYCT. Rail scheduling is discussed briefly. Unlike bus scheduling, rail scheduling has been largely a manual job, which is only now being automated using Hastus.

Organization of the Schedules Department

The NYCT Schedules Department is organized by mode, with a Senior Director for Bus Schedules and for Rail Schedules. Both directors report to the Chief, Operations Planning, who in turn reports to the Executive Vice President.

The bus side of the Schedules Department is organized along the lines of the Department of Buses (the NYCT equivalent to the Operations Department at other agencies or Bus Operations at multi-modal agencies). There are five divisions, corresponding to the five boroughs, and several depots within each division. Each depot has a scheduler assigned to it, and senior schedulers review all schedules within their divisions/boroughs. Each depot schedule manager is responsible for all scheduling tasks, including schedule development, blocking, runcutting, and rostering. Less senior schedulers perform all scheduling tasks except rostering.

There is an “Other” division within Schedules, which handles bus stops, distances between bus stops (in Hastus Geo), substitute bus service for rail track work, head signs, pick administration, statistical output, interface with everyone beyond Hastus, and distribution (picks and statistics) to the unions and to depot/bus division management.

All schedulers at NYCT are managers. Twenty years ago, schedulers were senior dispatchers, in the same union as bus operators. Level of service and efficiency are key management issues, so scheduling is a management issue. Classifying schedulers as managers is fully justified when one considers that the platform budget of $1.1 to $1.2 billion dollars over 20 depots translates to an average of $60 million per depot in service costs for which the scheduler is responsible.

The Schedules Department is more budget-oriented than other non-finance/administrative departments in NYCT. It serves as a facilitator between the Department of Buses and the Office of Management and Budget. Schedules meets regularly with the Senior Vice President, Department of Buses. Other departments and upper management have a high level of trust in Schedules’ numbers and cost estimates.

One thing that is emphasized more at NYCTA than other transit properties is that schedules and service levels are kept up to date very regularly, with a significant number of adjustments made

Copyright National Academy of Sciences. All rights reserved.

at every sign-up for load and running time changes. Schedule and service needs drive the platform budget rather than having a number handed down and scheduling to that number. Weekday schedules are adjusted every two years, and weekend schedules every four years.

NYCTA schedules strictly by service guidelines. Target loads are specified as a percent of seated capacity for different types of routes during different times of day. Recently the Board mandated a seated load as the midday and weekend guideline, when less than a seated load had been the guideline, but this was never fully implemented by NYCTA. The accommodation made is that service is not decreased to meet the seated load guidelines, but is not increased to allow for less than a seated load. Because weekend guidelines do not call for standees, there is greater flexibility in handling growth. Schedules are in a state of good repair. One area of concern is with p.m. reliability on the express bus routes.

The Scheduling Process

The Schedules Department works on an annual budget-driven cycle:

1. Platform Budget: In mid-winter, Schedules begins development of the platform budget for the upcoming year, strictly based on calculations for variable service needs – no initial consideration at this point of depot openings/closings or of any service planning recommendations. This process uses fall ridership numbers to determine peak ridership for the upcoming year. The Schedules database includes:

    a. All segment running times for each route
    b. Mileage for each route
    c. Trips per hour and ridership per hour from the most recent ridecheck – the ridecheck data is updated by the percentage change between the time of the ridecheck and the current fiscal year.

    Schedules then runs a model to identify the net cost of service requirements for the upcoming year. Model outputs include service hours, mileage, number of operators, peak vehicles, and cost stratified by route.

2. Service Plan: Schedules modifies the model outputs to take into account experience from prior years in areas such as running time, routes on diversion, and school service allowance. Service Planning (also part of the Operations Planning Division) and the Department of Buses provide input at this point. The result, in July, is a preliminary service plan for the coming year. At this stage, schedules is considering only regular all day routes. Express routes are handled slightly differently, as described in #5 below.

3. Formal Platform Budget: This budget takes into account all proposed changes and provides the basic framework for the upcoming year. This is prepared between July and mid-September and modified up until the December Board direction on the Authority budget.

4. Administration for January pick (city-wide pick): Schedules sends out the draft pick to the unions in September. For the January pick, Schedules has not been making guideline-related changes (i.e., changes to service levels to match load factor guidelines), because the budget has not yet been adopted.

Copyright National Academy of Sciences. All rights reserved.

5. Express routes: These are handled separately, within the same general time frame as the local routes. Each express route is scheduled to a seated load. The 35 bus schedulers check every express trip every year in the spring (this used to happen in September, but school opening, light riding on religious holidays, and UN week in Manhattan dictated a move to the springtime). Express schedules are adjusted based on these checks. Budgeting for future years' express service changes are based on both past experience and future population and employment changes. Express ridership has recently been declining due to a 67 percent fare increase (from $3.00 to $5.00 in two increments), reduced employment on Wall Street, and traffic congestion (Staten Island residents have been shifting to the ferry). Limited-stop buses and the proposed BRT services are/will be treated as local bus service in terms of guidelines.

6. Work on Spring Schedules. This begins in September, after the platform budget and work for the January pick are completed. Guideline-based changes are made in the spring schedules and are reviewed within Operations Planning and the Office of the Executive Vice President, then by the Senior Vice President, Department of Buses, the President, and the board. This step formally begins on November 1. By December 1, drafts of the proposed changes are sent to the Senior VP and the President for review and approval.

7. The summer and fall schedules follow the same process as the spring schedules. NYCT has been moving toward fewer summer-only schedules, reverting to the winter school-closed schedule as summer ridership continues to increase.

8. Traffic checks: the schedule of traffic checks for the upcoming year is developed in October, based upon when a given route was last checked.

Scheduling Issues

On Time Performance/Running Time

As might be expected in New York City, service reliability and traffic conditions are on-going and intractable problems. Schedules are continually adjusted through a process of communication with road supervisors and making adjustments to internal time points.

Schedulers do a lot of on-time performance work, looking at data and sharing observations with road supervisors. If Schedules can move on time performance (measured at all timepoints along a given route) by five or more percentage points, it has made an impressive improvement.

NYCT has an on-time performance program, involving 43 routes which are analyzed each quarter. Traffic checks for on-time performance are done semi-secretly at timepoints. The Schedules Department prefers ride checks to gather data for rescheduling, but will use point check data for that purpose.

Running times are calculated using a two-day average, and are correlated from timepoint to timepoint. The formal ridecheck is augmented by field work to verify running times. Automated Vehicle Locators are being implemented over time, with the first phase of implementation at the 126th Street Depot in Manhattan. NYCT has not yet determined how the AVL data will be utilized in the scheduling process, but is encouraged that the AVL can provide more frequent time checks than have previously been available through traffic checks.

Copyright National Academy of Sciences. All rights reserved.

Recovery Time

Providing adequate recovery time is considered as important as providing adequate running time. Recovery time is typically 10-15 percent of running time. Service planners help by breaking up very long Manhattan routes to improve reliability.

Relationship to Service Planning

Schedules works very closely with Service Planning, which relies on Schedules for realistic estimates of the cost impacts of any proposed changes. Schedules understands when you can do a marginal cost estimate and when you need to develop a full schedule to estimate impacts. A good relationship is the key: there is no pocket veto power on the part of Schedules and no rule by fiat on the part of Service Planning.

Timed Transfers

Timed transfers are used only in very specific circumstances: between a Staten Island limited stop bus route and the Hudson-Bergen Light Rail line in New Jersey; between subway and buses in owl service at Main Street Flushing and Jamaica Center-Parsons/Archer (both in Queens), and between the Q79 route and the Long Island Railroad at the Little Neck station. Bus frequencies are sufficient to allow for untimed transfers in nearly all other circumstances.

Interlining

Interlining has saved NYCT $2.5 million annually in the Queens Division and at least an additional $3.5 to $4.0 million in the rest of the system. However, interlining has caused problems with the unions, particularly in the borough of Queens. The chief complaint was stress on operators from the interlining. NYCT recently proposed not to interline some Queens routes, giving up $100,000 in savings in each of the three Queens depots, but stipulated that attendance must improve or the interlines will be reinstituted.

Swing Shifts

Straight and swing shifts are defined by the length of the break in the operator's schedule. Straight shifts have a break of less than or equal to one hour, swing shifts more than one hour. Restrictions on swing shift vary by borough: there is no restriction on swing shifts in Staten Island; no more than 45 percent in Queens; no more than 30 percent in the other boroughs. Breaks generally occur between the start of the third hour and the end of the sixth hour of work, but in Queens, only eight percent of breaks can be outside these parameters.

Extraboard

A "typical" extraboard includes trippers along with sick, vacation, and other unscheduled absences. At NYCT, trippers are called "extras" and are covered through overtime. NYCT's allowance for sick, vacation, and other unscheduled absences is set by past experience at 19 percent. The use of Hastus has reduced "extra" pieces by approximately 50 percent.

Computerized Scheduling

When NYCT began using Hastus as its computerized scheduling program, Schedules conducted parallel picks (manual and computerized). NYCT began with the Vehicle, Crew,

Copyright National Academy of Sciences. All rights reserved.

Crew Opt, and Roster modules, then customized and added modules. Hastus has helped in calculating the impacts of new depots on mileage and cost.

Even in an agency with a large number of trained schedulers, bringing Hastus on-line was challenging. Final acceptance happened 18 months after initial implementation. Most of the delays were on the NYCT end for two primary reasons: manpower shortages affected its ability to do the required testing; the introduction of Metrocard resulted in a need to increase service, diverting resources planned for testing. A 12-month process stretched out to three years. Each borough is also unique, both contractually and in terms of past practice. Long shifts are the practice in the Bronx, for example, while Brooklyn has a cafeteria pick for weekends. In retrospect, NYCT should have had more people involved in the implementation.

Hastus releases updates every two years, and Schedules would recommend a three-to-four year cycle for updates. NYCT is now purchasing Hastus for rail and wants very tight controls on what the program can do. As a result, computerized rail scheduling will not have the flexibility of bus scheduling. Hastus probably feels that the restrictions are “setting the program back 20 years.” The rail purchase is considered a modification to the current contract, not a new purchase, thus saving considerable money on licensing fees.

NYCT has a strong collaboration with Giro. Many of the upgrades introduced to Hastus were suggested by NYCT. NYCT schedulers have demonstrated Hastus for the Long Island Rail Road and New Jersey Transit. MTA’s timekeeping system already interfaces with Hastus.

Downstream uses started with the old DOS-based system, which was not flexible enough for change. NYCT had to get Hastus to make modifications, specifically in Rostering (could not accept alpha characters).
A key to the evolution of Hastus at NYCT has been improvements to the rule files, to the point where further tweaking is nearly unnecessary. Customization of rule files is critical to maximizing the value of computerized scheduling. However, manual fine-tuning of Hastus output is needed in a system as complex as NYCT. School service is a major cause of fine-tuning, along with balancing swings and spreads. In Staten Island, for example, 80 percent of the work is by Hastus and the remaining is done manually by the schedulers.

NYCTA credits the success of the automated system on their close relationship with the developer and on the availability of people who know and understand scheduling to work closely on procurement and customization of modules. It is very rare that a standard module will work optimally at any property out of the box, and it is crucial that the staff with the right skills works with the software provider to get the most out of the product. Creating a rule file that is as rich and accurate as possible is considered a key to optimization.

Every 0.1% reduction in vehicles per pay hour saves NYCT $2 million. With Hastus, the runcut Pay-to-Platform ratio has been reduced from 1.25 to 1.22, which seems small but has resulted in significant and recurring cost efficiencies of over $6 million per year.

Downstream Requirements

Downstream requirements have increased, but are not so onerous for several reasons:

1. Schedules has been able to organize around these requirements, with versatile staff and the ability to double up on smaller depots.
2. A budget line came with some added functions.

Copyright National Academy of Sciences. All rights reserved.

Vehicle Types and Effects on Schedules

Three different types of vehicles are scheduled:

1. MCI coaches for express service
2. Articulated buses, which have a different pay rate ($0.25 per hour higher). Articulated and "regular" buses are not mixed on a given route: if a route has articulated buses, then all buses on that route (with the possible exception of school trippers) are articulated.
3. Low/high floor "regular" buses

Treatment of low-floor buses in relation to service guidelines is an interesting issue. Starting with schedules for spring 2008, low-floor buses will be held to a maximum of 54 passengers per trip (on average) in the rush period, or 150 per cent of their seating capacity, rather than the 60-passenger load standard used for standard 40-seat high floor buses. Lines that have all low-floor or a mix of low and high floor equipment will be scheduled to the 54 passenger standard. This change in standard has become important as more and more low floor buses have arrived, and many garages are now mostly low floor.

Express Bus Schedules

Scheduling express buses is always challenging for transit agencies, due to the peak nature of demand for express services and the resulting need to deadhead. The opening of a new NYCT depot west of midtown Manhattan provided an opportunity to store express buses on the depot's roof during midday. NYCT reached an agreement with the Staten Island union to cap the number of buses stored in midtown (away from the originating depot) at 82, but this agreement does not preclude storing express buses from other boroughs at this location in the midday.

Labor Relations

Labor relations have improved to reasonably good levels over the years, possibly due to expansion of service. Queens has been an exception, due to unusual circumstances. Routes and buses have been reassigned from one depot to another, but in Queens an operator loses seniority and starts as a beginner if he or she moves from one depot to another. There have been no arbitrations recently.

Training

The Scheduling Department utilizes a training philosophy that it takes two to three years of manual experience to hone someone to be a scheduler. Realistically, pressures and deadlines can preclude this length of manual experience, but all schedulers start out scheduling manually before advancing to the automated system, based on a strong belief that a scheduler cannot let the computer run a schedule without knowing what it is doing.

The training process for new schedulers at NYCT includes:

1. How to analyze data. How to recognize and discount outliers. New schedulers are required to ride the line they are scheduling, to see major generators such as schools and to understand the location of the peak load point.

Copyright National Academy of Sciences. All rights reserved.

2. How to develop a schedule proposal. How to schedule by the guidelines. How to smooth the schedule and running time in transition periods.

3. How to prepare a trip sheet (Headway) on paper.

4. How to break the schedule (runcut) by hand.

NYCT will give new scheduling candidates a math test to test their aptitude, including questions that require time calculations in hourly format (e.g., time elapsed from the start of a trip at 1:37 p.m. and the end of the trip at 2:12 p.m.). Along with an aptitude for math, an understanding of scheduling basics (e.g., the importance of peak buses) is critical.

As new schedulers are training, they will be sent out into the field to resolve a complaint. They will develop a proposed solution and present it to the person training them.

Senior Management's Perspective on Scheduling

One purpose for conducting interviews with senior management is to understand how the scheduling function is viewed within the agency. For this case study, we interviewed two senior managers, and their perspectives are reported in this section.

In the past, senior management at NYCT has not paid attention to the scheduling function. Schedules has been looked at in the past as on the side, a minor annoyance. The view is shifting now to the belief that if you want to pay attention to customer complaints, then you have to pay attention to scheduling.

One perspective is that a good Schedules Department is like a good Maintenance Department in terms of preventing problems. Schedules is increasingly viewed by some as critical to the agency's performance. Upper management does not always realize the potential for savings from good schedules. Good schedules also contribute to the morale of operators. If operators are never on time, it results in higher absenteeism, rudeness to passengers, and more accident-prone drivers. Even with this heightened awareness, scheduling has a relatively low priority in the agency.

The Schedules Department is viewed as a production activity, responsible for delivering a product, and does not necessarily get credit for its achievements in a production environment:

1. It generates four schedules each year for the entire system
2. It conducts basic research, because it schedules by ridership through service guidelines
3. It carries out other program initiatives
4. It develops schedules
5. It negotiates schedules with the unions

As a production activity, Schedules needs to churn out its product. How can the scheduling function be improved?

1. Compress the cycle. It's now September: half of the January schedules have been sent to the union and Schedules is working on the spring pick.

2. Consider other data sources. Can we use Metrocard data as a data source? Checkers are expensive, and drivers may change how they drive with a checker on the bus. But

Copyright National Academy of Sciences. All rights reserved.

Metrocard data only supplies route, direction, and time of swipe – not alighting stop and time. AVL will make a difference when it is up and running. But AVL is currently limited to one depot, and the capital funding to expand it system wide may not be available.

Another problem is how to deal with variations among drivers and in day-to-day demand. What is the width of the bell curve of drivers, and how does Schedules address this? How do you schedule a route on a retail corridor with very light traffic on Monday and Tuesday but increasingly greater traffic on Wednesday through Friday?

It is also important to keep Schedules involved in the purchase of new vehicles. New hybrid buses have lower seating and standing capacity, and this clearly has an impact on Schedules in an agency that prepares schedules according to guidelines. The original decision to schedule low-floors the same as high-floor buses in terms of allowable loads is being modified, as noted earlier.

Other questions that Schedules provides important answers to include:

- What lines can we put articulated buses on for the biggest savings? And, do articulated buses fit in the depots out of which these lines operate?
- Where is home for the buses? Reorientation of lines by depot might be necessary.
- Can we split lines between depots to get savings? A recent example on the MTA side was to move 10 buses on the QBx1 route to a depot in Eastchester to produce savings.

From an operational perspective, it is important to define the causes of a problem before asking Schedules to make adjustments. On-time performance can be affected by many factors. For example, the M14 bus carries over 45,000 riders per day and is chronically delayed. Field work found that traffic delays were caused in part by buses not pulling fully out of traffic into the bus stops.

Schedules is not really a budget function. It has serious budget implications, but NYCT does not turn to Schedules to squeeze X million dollars out of the budget. Sometimes there is a service reduction goal in a budget shortfall situation. Reducing service falls to Operations Planning as a whole. Schedules never cuts recovery time, because some degradation in performance reliability results. Generally, budget cuts come out of programmatic services, such as cutting back late-night or low-ridership routes.

When NYCT purchased Hastus, the talk was that the software tools would allow NYCT to write more efficient schedules. It is not clear to upper management if this has happened. Ridership has been increasing, driving up service costs.

The former perspective that overtime was bad is changing. With the fixed portion of medical benefits going up, an hour of overtime costs nothing compared to the cost of regular time with an additional operator. It may not be especially efficient, but it is comparable to an individual buying insurance as a safeguard.

It is also important for Schedules to work hand in hand with the Department of Buses. Two examples demonstrate this. When the M60 (between upper Manhattan and La Guardia Airport) route was relatively new, drivers said that the bus was packed by the time it got to 124th Street and Third Avenue. The Department of Buses confirmed this through fieldwork and relayed the information back to Schedules, requesting additional buses. Schedules added service at the next pick, and the Department of Buses lobbied for its inclusion in the budget

Copyright National Academy of Sciences. All rights reserved.

The second example is related to the redevelopment of Gateway Mall. Working with Road Operations, Schedules led the agency to the right path in terms of ingress, egress, stop locations, and operator facilities. The ability to work together and to communicate is very important. Schedules decides what is needed on the road, Road Operations tells schedules where operational problems could (and do) arise and how these might be addressed. Schedules and Road Operations are both critical to customer service.

An interesting aspect of the Schedules Department at NYCT is that it is independent of other influences. It is independent of the Office of Management and Budget. It is independent of the Department of Buses (an AGM at a depot can complain about a schedule, but Schedules can come back and say we looked at it, we do not agree with the complaint, and we are not going to change the schedule). It is independent of the unions. If Schedules were to become part of the Department of Buses, a scenario of "horse-trading" with the unions could occur. In other organizations, the Schedules Department could be subservient. An independent Schedules Department is viewed as a very positive state of affairs.

E.13 Toronto Transit Commission Case Study

Introduction

Toronto Transit Commission (TTC) operates transit service in metropolitan Toronto, Canada. TTC is a significant North American transit property, operating over 1,300 peak buses in addition to LRT, Streetcar and heavy rail (subway) services. TTC operates 138 bus routes, 11 Streetcar routes, 3 subway lines and 1 LRT line. All but one of the bus routes connect with heavy rail network. There are over 3,800 full time operators employed by TTC. The peak-to-base ratio for the bus network is 1.7.

The network is predominantly grid-based, with high-frequency bus services operating on major roads, often with long (and in many cases 24-hour) service spans. Many routes are effectively cut into two at the key subway route, resulting in an almost quadrant-based network of bus routes.

TTC is included in the case studies because it is a highly regarded, very large, multi-modal transit agency. Overall measures tend to indicate TTC schedules efficiently and effectively. TTC utilizes the Trapeze computerized scheduling software package to undertake scheduling tasks. The focus of this case study is on the bus operations aspects of TTC's operations.

Three individuals were interviewed for this case study:

- Bob Dorosch, Superintendent of Schedules
- Scott Haskill, Senior Transit Planner
- Jennifer Standen, Senior Scheduler

Scheduling Department Structure

Organizationally, the scheduling department is located within the operations division, and is a part of the service planning group. Figures E-3 and E-4 present an overview of the Service Planning Group (higher level only) and the Scheduling Department. The Service Planning Group has a total of 89 staff. The scheduling Department has a total of 20 staff, and is directed by the Superintendent of Schedules.

Copyright National Academy of Sciences. All rights reserved.

Figure E-3
TTC Service Planning Group Structure

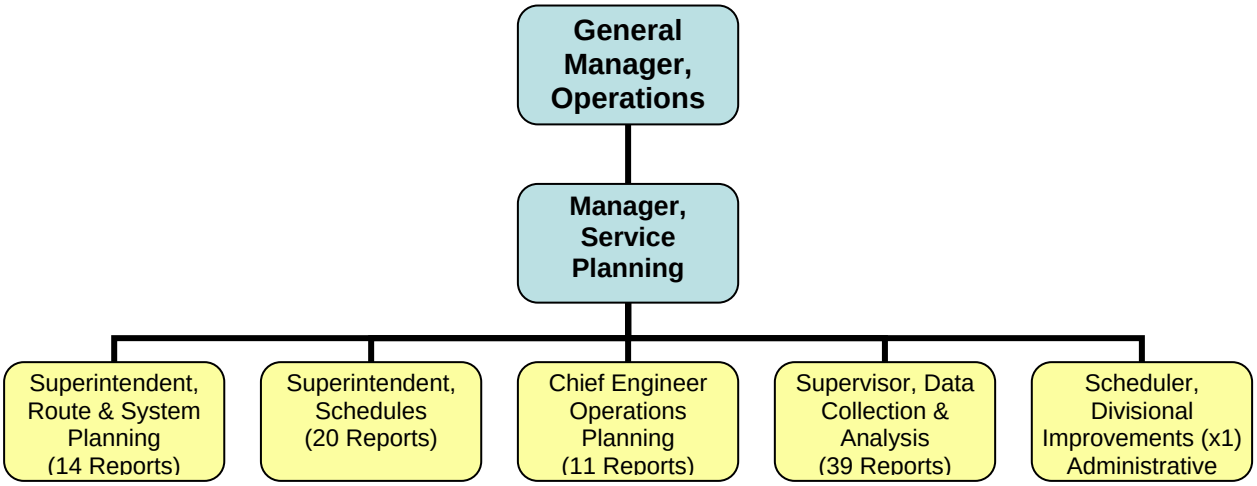
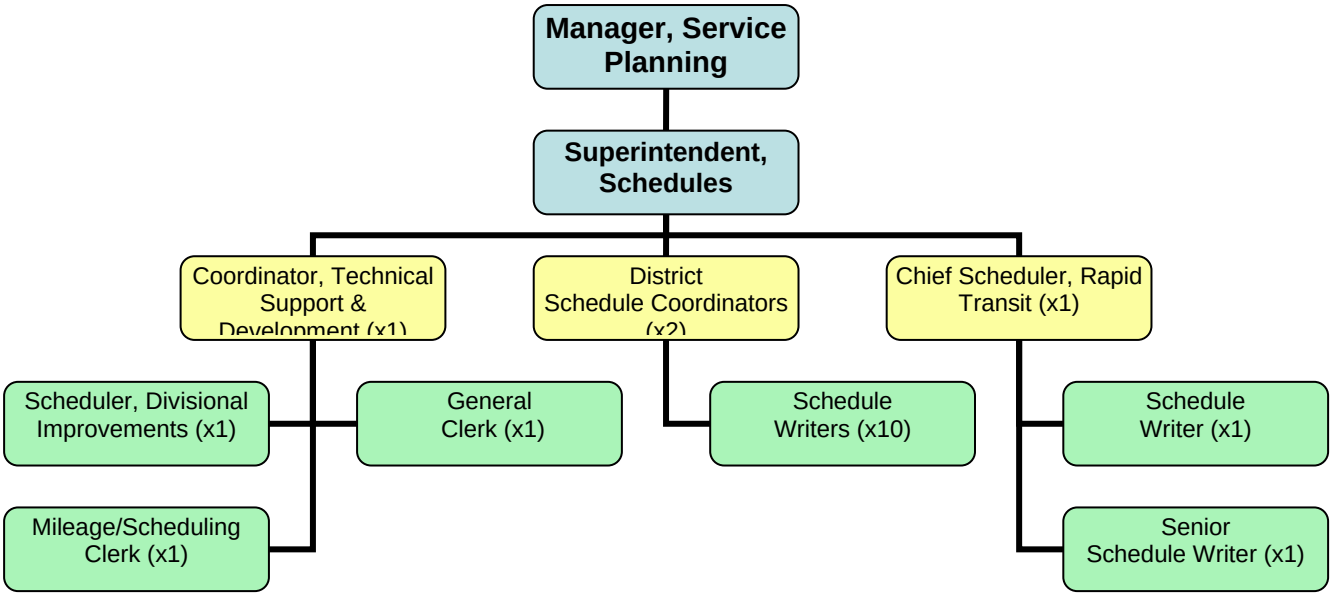


Figure E-4
TTC Scheduling Department Structure



The Schedules department is split into three functional areas:

- *Technical Support*, including internal IT, production and specific scheduling support functions. The scheduling department has its own separate office location independent of the rest of the organization. The department has its own internal IT support. All of the

Copyright National Academy of Sciences. All rights reserved.

internal IT support staff have some form of scheduling background, which enhances the support that can be provided to the department.

- *Schedule Writers*. The schedule writers perform the traditional scheduling function, inclusive of schedule writing, blocking and runcutting. Work is split up on a region or garage basis. Typically a schedule writer is responsible for one garage, of 180 to 260 vehicles in size.

- *Rapid Transit Scheduling*. Rapid Transit schedulers are focused completely on the subway and station collector services.

The background of scheduling staff varies. Of particular interest is that none of the schedulers has an operator background. The Scheduling Superintendent prefers to consider 'people without blinkers' when sourcing potential staff.

The career path laid out within the scheduling department is as follows:

Trainee Schedule Writer ➡ *Schedule Writer* ➡ *Chief Scheduler* ➡ *Scheduling Coordinator.*

The department has a highly stable workforce. In fact, no scheduler has left the department (expect for retirements) in over ten years. The number and multiple skills of staff allow flexibility in utilization of resources. This allows the scheduling department to deal with varying workflows. The Scheduling Superintendent primarily has an oversight and leadership role.

The Scheduling Process

TTC operates an ongoing system of signups. Being a larger, multi-departmental organization, TTC requires extensive documentation and procedures for its scheduling process. The Scheduling Coordinators and District Coordinators employ tight record-keeping procedures. The primary scheduling tasks undertaken for each signup are provided below:

Signups. The scheduling process at TTC is heavily governed by the ***ten*** annual signups, known as 'Board Periods'. None of the Board Periods operates for longer than six weeks. This requirement naturally places a significant burden on the scheduling department - at any one time there may be multiple signups (typically three of four) in various stages of completion. The requirement for ten signups is primarily based on historical practice.

For any given Board Period there are a number of service changes, at times quite significant in volume. The internal document that summarizes the changes for the November 2007 signup is 18 pages long. For each signup all 4,300 operators rebid the available work.

One benefit of the multiple signups is that TTC is able to respond reasonably quickly to changing service needs. It also ensures an ongoing error detection and correction process.

Service Changes. Service changes are driven by the Service Planning Department. The service change process includes the following steps:

1. A draft proposal for service changes is provided by service planning, inclusive of a draft budget
2. This document is followed by a set meeting of key stakeholders throughout the organization

Copyright National Academy of Sciences. All rights reserved.

3. The Scheduling Superintendent presents the plan to the scheduling department
4. Schedulers undertake the scheduling process over a five-week period
5. The bid process is undertaken

Service Change Requisition forms are used to track service change requests.

Service Levels. Service levels at TTC are set by the Service Planning Department and refined in an iterative process with the schedulers. Service planners provide direction to the scheduling department based on the number of buses to be run on a route, rather than the headway to be provided. This direction is called the service specification. The direction to schedulers, for example would be, “add 2 peak buses to Line 35 for a total of 9”. The service planners base the calculation on service levels and running times. The directions provided to schedules are intended to achieve a general level of service, but the schedulers are given the flexibility to optimize within the allocation of vehicles.

Service Planning provides highly prescriptive service specifications for short turns, branches and express operations. The specification also includes garage assignment requirements by route. As schedulers work on development of schedules during signups, there is ongoing informal feedback with the service planners. This feedback loop operates in both directions.

Most routes operate at high frequencies. In fact there are no published timetables, just route and generic frequency information. All-night owl service is operated on 24 of the 175 bus routes.

Service standards applied are based upon an average peak load of 59. Currently the Service Planning Department is rethinking this standard with a view to possibly reducing it to 52. Seated capacity of vehicles is 39. TTC undertakes a sophisticated analysis of manually-collected point count data, using an internally-developed application, to develop proposed service levels.

Running times. Running times are set by the scheduling department. The sources of information include AVL, paper checks, operating division input, and scheduler fieldwork. Running times tend to be set ‘tight’ along the route and the last segment is then padded. This approach is applied to avoid early running but allow sufficient time for next trips to depart on schedule.

Trip patterns. TTC operates a range of patterns. Some particularly complex routes operate with multiple branches, short turns, and express & local stopping patterns, sometimes all combined on one corridor. As routes converge, there are a number of corridors with multiple routes in operation.

Span of service. TTC operates a wide range of spans across its extensive route network, including peak-only, owl, and most combinations in between. Service spans are set by service planning. Experience suggests that any elimination/alteration of first/last trips has been highly sensitive.

Building the schedule. The schedulers build schedules according to the service specification. As described above, the specification gives the number of buses to be used. The scheduler then basically generates the highest level of service achievable with that number of buses, within the constraints of cycle times. It is assumed that this will equal the intended service level estimated by the service planners. When updating a schedule, the schedulers typically will delete all existing trips and rebuild the schedule from scratch. They will try to reconstruct those parts of the schedule that are not changing. This part of the process is not overly complex. The greater difficulties come where service patterns are more complex.

Copyright National Academy of Sciences. All rights reserved.

A large percentage of schedule-building time is spent on transition to/from peak periods. Schedulers manipulate running times, layovers and frequencies to achieve the best possible transition. This includes significant review of run cut impacts, such as block lengths and pre/post-peak pulls.

Timed transfers are only scheduled at times of lower frequency, predominantly late at night or on the owl services. On many lines early/late trips are scheduled to meet first or last trains. A three-minute transfer window is typically scheduled.

Blocking. Blocking is undertaken on a line-by-line basis in Trapeze. This approach is typical of larger systems where each route has enough service (and therefore uses enough resources) to operate efficiently on a standalone basis. The efficiency of blocks is in effect controlled by cycle times and prescribed service levels.

Some minor interlining is undertaken once blocks have been completed for each line. As blocks are created, great care is taken to consider impacts on the run cutting process.

Runcutting. Schedulers at TTC spend the majority of their time undertaking run cutting. The Scheduling Superintendent estimates approximately 60 percent of schedulers' time is accounted for by this task. The weekday pay/plat ratio is 1.14.

The schedulers tend to take the approach of creating runs interactively, (that is, some runs are created manually and some are created by running the automated run cutter – but the solution is never completely generated automatically), and then using the 'improve' functionality to rematch pieces, alter reliefs, and optimize according to defined rules. This approach allows the schedulers first to control the structure of the run cut, and then to attempt to optimize efficiencies within that preferred structure.

The runs are created in the following manner:

1. Create night & owl runs
2. Create straight runs (cut line by line, very similar to the service curve for that line)
3. Use the remaining pieces to create split runs
4. Use the automatic improve feature to optimize the solution

Steps two to four are often repeated many times, sometimes with some of the runs (particularly straights) frozen before the automatic improve feature is run.

All runs are created as straights or splits. There are no tripper or part time runs created, except where staff shortages may dictate, and some trippers are left over to be operated on an overtime basis.

Pay-to-platform ratio is used a basis for measuring the efficiency of an individual run cut and the trend from run cut to run cut.

Rostering. Weekly lines of work (a series of runs spread across the week, inclusive of days off) are built by scheduling staff. Operators then pick those lines of work. The exception to this is Sunday work, where lines of work are simply assigned as Sunday on or Sunday off. If an operator picks a line of work with Sunday 'on', they then choose from the available runs. This requirement means that Trapeze is used to generate completed rosters for all divisions. Most of

Copyright National Academy of Sciences. All rights reserved.

the roster creation in Trapeze is undertaken using the automated features, after the days off patterns have been manually developed (i.e., Trapeze fills the empty slots automatically).

The development of rosters typically takes only half a day per signup period (per division).

Key Scheduling Issues

Running Times

TTC tends to take the approach of tightening running time (slightly below the assumed requirement) along a route and then 'padding' the time for the last segment. Average times are generally used for end-to-end running times, based upon available data.

A concerted effort is made to review running times around peak shoulders and on early/late services. By keeping running times during these periods from increasing too closely to peak periods (which can happen if there are too few run time periods, for example), TTC is able to minimize spread penalties, overtime, and related costs.

Scheduling staff indicated a preference for fewer timepoints along a route (every 10-15 minutes was suggested as preferable) to keep buses moving fast. There is some natural friction between field operations and scheduling staff with regard to running times, where operations staff are tending towards more running time increases.

Running times are set by scheduling staff from a variety of input services. There is some ongoing debate between the Service Planning and Scheduling Departments as to who should be responsible for running times development.

Layovers

TTC operates with a scheduling (not contractual) requirement of two minutes minimum layover at the end of each trip. Unlike most agencies, TTC layover tends to be a function of cycle times, frequency and bus requirements, *not* a driver of cycle times. Many routes operate at high frequencies and therefore layover is kept to a minimum. Layover currently represents approximately five percent of platform time.

Interlining

TTC takes a policy view that interlining is a) generally not required (due to the high frequencies of service and grid-based network structure; and b) not a preferred operating approach. As a result there is little interlining – somewhere around 10 percent of trips at most. The operation of long, high-frequency services allows each route to be blocked on a standalone basis while maintaining efficiency levels.

Some interlining is used where service levels are lowest and operational impacts will be reduced, such as for late evening and weekends services. Some school specials are interlined with peak buses to form longer blocks, particularly during the PM peak.

Owl Services & Scheduling

TTC operates all-night services on 24 'hybrid' routes. The term 'hybrid' here means routes that generally follow the subway lines, in effect providing all-night subway coverage.

Copyright National Academy of Sciences. All rights reserved.

Scheduling of owl services inherently presents scheduling complexities. When does the service day end? When does the bus pull in, or does it cover part of the next day's schedule? How is a relief handled, where effectively the driver from one day is handing over a vehicle to the driver on the next day, yet these need to be incorporated into one schedule?

The complexities become more significant as service types change. For example, a block that operates on a Friday and overnight on the owl service then needs to have the early Saturday block attached to it, since it will actually operate some of that Saturday block. This of course cannot be done until after the Saturday blocks have been completed. And in creating these blocks particular attention must be given to mileage limits based on fuel capacity.

TTC uses a 36-hour clock to allow a particular schedule to include the start of the next day's schedule, and to create blocks and runs accordingly.

Owl blocks on the bus network pull in before the AM Peak and the blocks start/end then. For the streetcar service, where the vehicles themselves have no mileage limits, operators change over around 1 a.m. and then operate through the AM Peak**.**

Vehicle Type Constraints

TTC operates a bus fleet consisting almost entirely of forty-foot vehicles. The constraint of vehicle types is the requirement for accessibility. TTC is committed to accessible operations of particular routes, or branches, or times of day. This adds complexity to the scheduling process and implies blocking constraints.

The blocking process for dealing with vehicle type constraints is handled in an interactive manner with Trapeze.

The fixed rail operations have specific vehicle type requirements and car/consist limitations, typical of similar operations.

Work Rules

TTC operates with basically no part-time or tripper runs. All runs are created as straights or splits, with the difference relating to breaks (see below).

The spread limit of 12:30 on splits (12:00 on weekends) is seen as a limitation, particularly as the peak extends. While the rule allows for 12:30 spreads, TTC schedulers attempt to stay within 11:30 where possible.

There are some 'special crews', with shorter work time and lower rates of pay. These account for approximately 15 percent of all runs. The lower hours of special crews result in increased pay/plat levels. However, these runs are required due to spread constraints. In many ways, these special crews are similar to part time operators.

An interesting feature of the scheduling process at TTC is that no paddles are produced. Operators literally write down their own times from available information and are paid a 10-minute allowance to do so.

Copyright National Academy of Sciences. All rights reserved.

Reliefs to points requiring travel on a bus are provided with travel time based upon walk time + half the scheduled headway + average run time.

The maximum run length is “eight hours plus half the route cycle time”. In practice TTC is able to build runs of over nine hours.

Penalties are cumulative and applied over top of other penalties, e.g., overtime penalty is applied on top of spread time and may result in doubling of costs.

Meal Breaks

The TTC contract requires non-owl operators to have scheduled meal or rest breaks. The breaks must be at least 15 minutes. If the break is 15-30 minutes the break is paid and the run is a straight. If the break is greater than 30 minutes, the run is created as a two-piece split. Sixty-six (66) percent of runs must be straights. Breaks must be taken after 8.30 a.m.

The majority of breaks are handled through step-backs, with some block reliefs. Block reliefs are runs where blocks are recut, with built-in layover sufficient to meet the break criteria – effectively slipping back the linkup by one trip. The 66 percent straight minimum requirement is seen as a significant limitation on run cut efficiency. Block reliefs are more costly but allow the straights percentage to be maintained.

Extraboard

At TTC, the extraboard is known as the ‘Spare Board’ and ‘Vacation Swings’.

Vacation swings are set at around six percent during non-summer periods and ten percent during summer periods.

The Spare Board is set at around seven percent of total division operators. This is based upon historical absence levels. It is kept lower than absences to allow for ongoing available overtime.

Use of Overtime

TTC considers that prudent use of overtime is more efficient than hiring additional operators. Benefits are higher than 50 percent of salary and therefore this approach appears to be appropriate.

The maximum shift length limitation places a natural ceiling on scheduled overtime. Use of unscheduled overtime is limited by the Canadian requirement for a maximum 48-hour workweek.

Some 4/10 workweeks are utilized, up to around ten percent of all packaged workweeks.

Computerized Scheduling

TTC has been a long term user of computerized scheduling tools, commencing with RUCUS in the mid 1970s. TTC was an early Trapeze client (late 1980s) and has undergone several system upgrades.

Copyright National Academy of Sciences. All rights reserved.

TTC's scheduling process appears to have been developed over a long period of time to work in harmony with the strengths and weaknesses of the system. This is a benefit of having been a long-term user of a single computerized scheduling package.

Downstream Requirements

There are a number of downstream systems that require scheduling data to function. These include:

- CSS (signaling)
- Dispatch (a series of spreadsheets, one per division)
- AVL

One interface export is undertaken for each signup, upon completion of scheduling work for that signup.

The TTC Scheduling Department's approach is to allow other parts of the organization to access the information and to generate outputs necessary for internal uses, i.e., it is not the responsibility of the Scheduling Department to develop & maintain 'non-core' scheduling data. As an example, the Scheduling Superintendent did not even know that scheduling data was being used by other functional areas as a basis for voice annunciation systems.

This approach tends to keep the scheduling department focused on core scheduling issues and pushes the responsibility for maintenance of data to those systems wishing to use that data. The staff responsible for maintenance of stops data is not even part of the scheduling group.

Scheduler Training

TTC has a strong internal training focus and process for schedulers. There is a two-year training program for new schedulers. The program commences with teaching manual scheduling skills and strategies before use of computerized methods are taught.

As part of the training process a new scheduler will undertake a parallel scheduling process during a signup (in addition to the actual scheduler). This allows feedback and development before a scheduler 'goes live'. The District Coordinators provide a mentoring role to developing schedulers.

There are a range of internal help documents, cheat-sheets, and reference documents. There is a specific internal "do's and don'ts" document distributed also.

The Scheduling Superintendent has a long history of developing and teaching scheduler training courses.

Copyright National Academy of Sciences. All rights reserved.

Organization Issues

At TTC the Service Planning Department clearly takes a strong role in schedule development. The specification is provided to the scheduler in great detail – number of buses, how many pullouts from each garage, etc.

This approach requires service planners and schedulers to work very closely in a highly iterative process. It is inevitable that some friction will result, particularly as schedulers feel they have little room to move at times. Ideally service planners would like to be able to develop draft schedules within Trapeze. However, schedulers may feel threatened by this.

It is also interesting that while service planning provides highly detailed and prescriptive service levels specifications, run times are set within the scheduling department. Again some friction is likely to result.

TTC's Views on What the Scheduling Manual Could Include

There were several issues noted that TTC believe are important to cover in the scheduling manual. These include:

- Trip Building:
  - A strong focus on how to build schedules with headway transitions
  - Understanding the importance of running times in building schedules
  - How to schedule in half minutes, or even seconds, to maximize efficiencies

- Blocking:
  - Knowing the answer/outcome before the scheduling work commences
  - Fully considering the run cut implications of blocking alternatives

- Run Cutting:
  - How to deal with operator breaks, including the alternatives
  - Elaborating on the various efficiency ratios
  - Considering operational and qualitative factors in developing run cut solutions
  - How to produce quality run cuts using computerized systems while reducing the amount of manual intervention required

E.14 TriMet (Portland OR) Case Study

Introduction

TriMet (Portland, OR) operates approximately 530 peak buses and another 75 rail (LRT) vehicles. There are 3 bus garages and 2 LRT yards. . There are over 90 bus routes and 3 LRT services. Base services levels are reasonably high, with a peak-base ratio of 1.7.

Tri-Met implemented automated scheduling, using Giro's Hastus software in 2001. This case study is particularly useful because Tri-Met has fully implemented automated scheduling relatively recently, and is in a good position to compare pre-and post-automation results. TriMet purchased the Hastus system in 2001 as part of a wider technology upgrade. Hastus replaced a previous internally-developed system (Interactive Schedule Maker).

Copyright National Academy of Sciences. All rights reserved.

Interestingly, TriMet undertook extensive analysis in deciding which system to purchase including asking potential vendors to produce run cuts. This allowed TriMet to compare potential efficiency impacts, a key element of assessing the overall financial impacts of scheduling software.

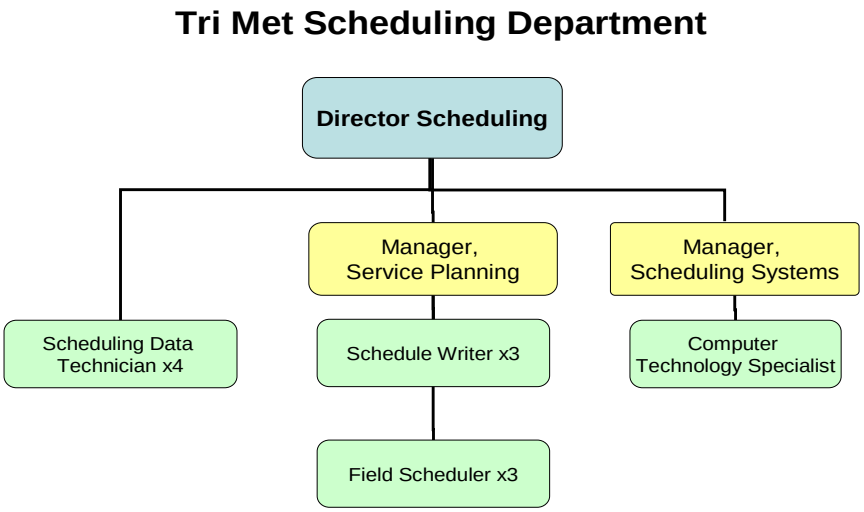
Some initial problems occurred where the schedulers allowed Hastus to produce automated solutions without enough constraints. The result was apparent cost savings that came with significant operational issues. Since then the rules/parameters have been refined and the system produces more operationally-sound outcomes.

The size and structure of the scheduling department did not alter as a result of computerized scheduling.

The TriMet scheduling department is overseen by the Director of Scheduling. The Director reports directly to the Executive Officer of Operations.

Figure E-5 summarizes the TriMet scheduling department organization structure.

Figure E-5
TriMet Scheduling Department Structure



For this case study, the following individuals were interviewed:

- Bill Coffel – Director, Scheduling
- James Hergert – Manager Service Planning
- Tim Garling – Senior Director of Operations
- Denis Schutt – Manager Scheduling Systems
- Bryan Gillespie – Schedule Writer 2
- Doug Allen – Computer Technology Specialist
- Jon Lutterman – Computer Technology Specialist
- Terry Bryll – Computer Technology Specialist
- Rex Fisher – Scheduling Data Technician

Copyright National Academy of Sciences. All rights reserved.

Scheduling Process

There are four bids per year. The September bid, occurring at the start of the school year, tends to have the most changes. Any given bid will have numerous minor changes, including significant updates to running times. For a "typical" bid two or three schedules will undergo a major re-write. Changes between sign-ups are allowed but are typically handled by the extra board.

Everyone involved in the scheduling process at Tri-Met is very technology- savvy. Tri-Met schedulers have developed their own internal tools for displaying and controlling the large amount of information that needs to be reviewed for a schedule bid. As an example, schedulers have developed a method of overlaying the new schedule on a time/distance graph over the old schedule. The old service shows as a different color or style, allowing one to very easily see what has changed. This also acts as an excellent quality management tool.

The schedules all appear to favor the use of graphical screens to view schedule information, e.g., time/distance graphs over working timetables, run graphs over run lists etc. Other innovations include linkages with many other automated systems that use scheduling data, described later in this case study.

The scheduling department divided into three "streams", each handling a different part of the scheduling process:

- First, there are the Schedule Writers (three positions), who are responsible for basic service design (particularly run times analysis). Service design work undertaken by the Schedule Writers is limited to minor trip adjustments, since service levels are dictated by service design staff (outside of the scheduling department). The Schedule Writers roles are split into rail (one) and bus (two, by region). Reporting to the scheduling makers are the recently-introduced field scheduling officers. Their role is to bridge the gap between scheduling and the operating garages, by having roving scheduling staff, whose role is primarily to investigate issues through data collection and by working with garage staff and operators. The goal is to enhance the communications between scheduling and operating staff.

- Second, there are Scheduling Data Technicians (four positions). Their roles are primarily focused on production and dissemination of scheduling information, such as reports, paddles, timetables etc. Each of the positions has a specific focus – for example, one of the technicians is a graphic artist and therefore focuses on timetables & maps. Another works almost exclusively with AVL data systems.

- The third stream is effectively an IT group within scheduling. The four staff members have extensive experience in scheduling systems (around 25 years each). Each of the four has a specific area of expertise. The staff has significant experience in scheduling systems and interfaces.

The advanced blocking and all runcutting functions are undertaken only by the Director of Scheduling and the Scheduling Systems Manager, the two senior staff in the department.

The schedulers are part of the drivers union. This is not seen as an issue.

Copyright National Academy of Sciences. All rights reserved.

The typical steps in the scheduling process at TriMet are:

1. The Service Planning department provides a specification, generally routes and service levels (not running times).
2. Schedule writers adjust/write the schedules, which are reviewed by multiple staff where possible.
3. Initial route-level blocking is undertaken.
4. The blocks are then loaded together and a systemwide review is conducted to look at opportunities for hooking block starts/ends to minimize peak vehicles.
5. The Director of Scheduling then reviews the blocks and provides feedback to the schedule writers. This is an iterative process.
6. The Director of Scheduling refines the blocks to allow for efficient run cutting.
7. The Director of Scheduling undertakes run cutting.
8. The bidding process occurs.

Scheduling Design & Blocking

Service levels, routing changes and changes in frequency are generally provided to the schedule writers by the Service Planning Department. Any changes made by the schedulers would be designed for efficiency and would not deviate significantly from the parameters provided by service planning. The primary catalysts for service changes tend to be a mix of service level requirements, operator complaints, run time updates, and construction projects.

The schedule writing and initial blocking tasks are undertaken by Schedule Writers. In recent years, TriMet has generally been in a 'service reduction' mode and therefore the focus has been on finding improved efficiencies. The majority of blocking is undertaken interactively within Hastus, or by using the basic/simple blocking functionality.

Prevailing service design characteristics include the use of clockface headways running 15, 30 or 60-minute intervals, and a 15%-17% system-wide recovery time target. The minimum standard for recovery time is 10% on a per trip basis, although occasionally this may be reduced to eight or nine percent as a stop-gap measure to make a schedule. There appears to be a tendency to accept higher-than-mandated layovers as necessary to ensure service reliability.

The Schedule Writers are responsible for review and update of running times. TriMet has advanced tools available for analyzing data at trip level and has built an interface to import AVL data into the Hastus ATP system. Schedule Writers work with Field Schedulers "to add knowledge to the data" when analyzing running times.

TriMet operates at 82% on time (1 early to 5 late). This is broken down into 12% late and 6% early. This is exemplary for an urban transit system recording information at every timepoint on every trip. Reliability is an issue on Tri-Met's longest routes; particularly routes that have been combined to avoid overlap through the downtown. These routes can require up to two-hours for one-way travel time.

Interlining tends to be limited to hooking the ends of blocks together once route-level blocking has been undertaken. There is a sense that interlining is 'bad' operationally.

Copyright National Academy of Sciences. All rights reserved.

TriMet sees headway maintenance/spacing as a key emerging issue for service quality. The result is schedulers are now giving greater consideration to this issue when developing schedules.

Runcutting

Runcutting is the purview of the two managers in the department. TriMet uses Hastus CrewOpt to automatically undertake run cuts. Very little fine-tuning of automatic solutions is undertaken as the Hastus results are considered to be very good.

The runs are comprised of straights, splits and part time. Spread overtime applies beyond 12 hours.

Key run cut issues for Tri Met include meal breaks, overtime levels, part time operators, and extraboard operators. These are discussed below under “Scheduling Issues.”

Rostering

Rostering at TriMet is undertaken on a cafeteria bid basis, where the drivers assemble their work week by bidding on individual pieces of work for each work day. Therefore the scheduling department has little input. The data is sent to an internally-developed bid system which is managed/administered at the garage level.

Scheduling Issues

Meal Breaks

Meal breaks constitute the key constraint to runcutting. 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 23% of runs can involve a vehicle change. This limits options to create multi-piece runs to deal with the breaks.

The outcome of the breaks requirements is that higher levels of layover are built into the blocking patterns and as a result longer layovers are repeated several times throughout a run.

Overtime Levels

TriMet firmly believes that increased overtime is more efficient and ultimately less expensive than adding operators. Operator benefits alone currently run at around 40%.

The department had undertaken some specific analysis of the trade-off involved with high overtime runs, including the opportunity for higher absenteeism, fatigue-related accidents and

Copyright National Academy of Sciences. All rights reserved.

other quality of life impacts. The analysis to date indicated that longer split runs tend to have fewer accidents than longer straight runs, but also tend to have high absenteeism levels. The agency remains concerned that high overtime runs may have an impact on safety; however driver shortages have required that the existing practices be continued.

Part-Time Operators

TriMet operates with a significant part-time (PT) operator workforce. Part timers currently run at 30-35% of full-time runs, which equates to almost 300 part-time operators. PT operators are limited to 24% of the total number of operators. There are few work type restrictions, and there is no daily hours limit, e.g., a PT operator can work 3-10 hour workdays. Part-time runs can also be two small peak pieces with an unpaid break. This flexibility reduces limitations on the run cutting process.

One reason PT operators are so important to TriMet is that their PM peak vehicle requirement is between 30 and 40 buses higher than their AM requirement, resulting in many shorter single piece runs. Because the part-time workforce is so critical to the operation, it is considered the career path for full-time operators. All full-time bus operators are hired from the part-time pool. The career progression also requires that new LRT full time positions be offered to full time bus operators. There are no part time LRT operators. During recession periods, where few full time operators leave, part time operators have tended to turn over more frequently as their opportunities for progression are reduced.

While the reliance on a part-time workforce allows TriMet to operate more efficiently, it does have some negative impacts on the quality of life and morale of operators.

Extra Board Operators

The extra board is sized at a flat 15%, based upon past experience. The Director of Scheduling determines the size of the extra board. There are over 50 rules governing operation of the extra board, which limits their utility to the operation. This has led to a belief that the extra board size is driven by budget rather than by realistic needs, and tends to confirm the operator's belief that the agency relies on part-timers rather than full time extra board positions.

Downstream Systems

TriMet is relatively technically advanced with many leading edge applications. These place a significant burden on the scheduling task. Downstream systems that affect the requirements of the scheduling task include:

- AVL. The AVL system requires detailed schedule data and detailed stop geometry. The system produces a huge volume of data for further analysis. Interestingly though, the system is not used to proactively track, manage and adjust the service in operation.

- APC. The APC system also requires detailed scheduling and geographic information.

- Payroll. Planned runs information is exported to the payroll system.

Copyright National Academy of Sciences. All rights reserved.

- Bus Stops System. A two-way interface between the Hastus Geo module and TriMet's internal ArcView stops management system is built and maintained.

- Bid System. TriMet has an in-house windows system to manage the operator bidding process. This system requires Hastus to produce and export the runs information.

- Public Information. A range of public information is produced from both within Hastus and from TriMet's enterprise system.

- Journey Planner. An on-line journey planner is closely linked to the schedule and location data.

- Signal Priority. Buses are linked to traffic control systems. The system relies on schedule adherence information to decide whether to preempt or hold signals.

- Destination Changer. The vehicle destination signs are automatically changed through a combination of schedule information and the AVL system.

- Voice Annunciation. Stops are annunciated which relies on schedule and location data.

- Transit Tracker. Real time stop level information.

Although TriMet has highly advanced capabilities to export/import scheduling data, including direct manipulation of the Hastus system and Oracle database, the process is still cumbersome.

The number of systems clearly indicates a need for a vast amount of detailed scheduling data to be developed and maintained, in particular the operating patterns, stops information, and naming conventions. Accuracy of GIS information has been a problem and in fact TriMet used GPS on buses to trace the road network and have local authorities update their street maps accordingly!

There is a sense of frustration within the scheduling department that too much time is being spent manipulating data for downstream systems, reducing the amount of time effective scheduling work can be undertaken. The department's ability to adjust schedules quickly has been diminished. The Operations Director also noted this trend as an issue.

There are two basic scheduling data exports which are used to provide data to TriMet's enterprise system. This enterprise system then produced exports to the various systems. There is also the dual-direction link between Hastus Geo mapping and the ArcView stop maintenance system.

The key issue identified by TriMet staff is ***that schedules are more dynamic than the processing cycle for downstream systems***. This means that at times information in the systems is not up to date, or that schedule changes are held back until the downstream systems can be updated.

TriMet staff did indicate that the current detailed processes are probably part of an overall development/process improvement cycle, and that the process will (and must) become more streamlined. The number of Hastus exports has been reduced from 5 to 3 recently. This was

Copyright National Academy of Sciences. All rights reserved.

offset by concern that requirements and processing cycles are getting more complex. In addition, the next generation of some systems, such as AVL, is expected soon.

Customizing Hastus and Sharing Information across Properties

TriMet is very satisfied with their experience with the Hastus system and with Giro staff. They are on a 2-year system upgrade cycle. Tri-Met has developed numerous internal applications customizing Hastus and allowing it to produce automated reports that directly support scheduling and data requirements. Some of the internal applications developed by TriMet could be widely used in the industry but other systems are not aware of their existence and there is no good way to license and/or share this kind of information. TriMet would be interested in sharing their expertise and learning from others if there was an opportunity to do so.

Integration of Planning and Scheduling Responsibilities

The scheduling process used by TriMet tends to separate responsibilities between planners (who design routes), schedule writers (who take a route through basic blocking and never use Hastus' optimization features), and managers (who do the schedule writing and blocking and optimization tasks). This separation may result in people who are very proficient in the piece they are responsible for, but often fails to give line level staff the opportunity to see "the big picture". It is possible that planners and schedule writers would do a better job if they were part of the total process.

The newly-created position between the director and the schedule makers (effectively the Manager of the schedule writing and blocking tasks) has been filled by the former manager of service planning. This is also seen as a path to better integration with functions outside of the scheduling department.

Integration between Scheduling and Operations Functions

As with many transit properties there is some level of tension between the Scheduling Department and the operating department. Operations noted that if the Scheduling Department has a goal of schedule optimization within the allowable parameters of the contract this may result in schedules that are technically "legal", but are not in the best interest of the operation. Specifically, the use of part-time operators, assignment of overtime, etc. has an impact on employee morale, and especially in a tighter labor market may have a negative impact on driver availability.

One way the departments have attempted to work together is to assign Field Scheduling Officers to each operating garage to serve as a liaison between the Scheduling staff and the operating garages. This is an interesting and relatively unusual approach to this relationship. While the Field Scheduling Officers will develop a closer relationship to the operating needs at each garage, there is however some risk that the scheduling department will lose an element of control.

Support for Information Technology

As identified previously, the Schedule Department is very technology savvy and is required to support a number of innovative information products. Of the 15 total staff in the department, only five actually undertake traditional scheduling work. The rest are involved with information production and/or integration with downstream systems. As downstream systems become

Copyright National Academy of Sciences. All rights reserved.

increasingly complex, there is an increasing need for support staff, as well as for ensuring that these systems integrate together themselves to the greatest extent possible. Support for downstream technology is a major staffing issue going forward.

Scheduler Training & Career Path

TriMet has undertaken development of in house training manuals to support scheduler development. There are two key manuals that have been developed:

1. An innovative on-line version of the TCRP Basic Scheduling Manual. The manual was manually entered into HTML format and reproduced in a more user-friendly and interactive format.

2. A Hastus 'how to manual' The Hastus manual uses screen clips and brief descriptions to guide schedulers through Hastus functions and typical processes (e.g. how to create a trip, undertake basic blocking etc.). A technical writer was hired to assist in developing this manual.

Interestingly the on-line manual was used partly as a means to identify candidates for schedule maker positions.

Scheduler career progression has traditionally been limited in the scheduling department. Many of the staff, particularly in the information production and system support functions, have been in the same role for many years. All schedulers have come from operational ranks – in fact TriMet is obligated to fill all positions with ex-operators. Supervisory experience is also required (all supervisory positions at TriMet must come from the operator ranks.

The introduction of the Field Scheduler positions will provide some progression within the scheduling department – from Field Scheduler to Schedule Writer and then potentially to one of the managing positions.

Interestingly none of the current schedulers have manual scheduling experience. However TriMet is more than happy with the quality of the schedulers' work.

LRT-specific Issues

The LRT system has several unique issues/constraints to deal with:

- Prevailing service design characteristics include the use of clockface headways running.

- Development of LRT headways is severely constrained by infrastructure and signals. These include key junctions and single track segments (such as on the airport extension), interlocking requirements, and segments of common running.

- A 30-second dwell is added at a station just prior to the key system junction to allow reliable conflict movements.

- Longer post-peak layovers are built into the schedules to maintain reliability. This also allows break requirements to be met.

Copyright National Academy of Sciences. All rights reserved.

- The vehicles sometimes start and end at different yards. This has several blocking and run cutting implications. The number of vehicles at the start and end of day are balanced between garages.

- Relief-related delays have been an ongoing issue. Current TriMet goes back and manually adds 2 minutes of dwell time for reliefs (added in after run cut is complete and reliefs have been identified/finalized).

- Not all pull or yard trips are created as in service (which many systems do), but are left as pull deadhead trips.

E.15 Case Study Summary

A concise summary of all the issues discussed in the twelve case studies is not possible. The goal of the case studies, to explore how current scheduling issues are being addressed, has been well served by the variety of approaches taken by agencies of different sizes at different stages along the continuum of use of scheduling software packages. Common themes emerge around challenges in traditional scheduling functions, in adapting to new technologies that produce new downstream requirements, and in training the next generation of schedulers.

Copyright National Academy of Sciences. All rights reserved.