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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 126

Leveraging ITS Data for Transit Market Research: A Practitioner's Guidebook

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TRANSIT COOPERATIVE RESEARCH PROGRAM

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

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

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

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FOREWORD

By Gwen Chisholm Smith
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TCRP Report 126: Leveraging ITS Data for Transit Market Research: A Practitioner's Guidebook, describes currently used intelligent transportation systems (ITS) and Transit ITS technologies that have the greatest promise for transit market research. This guidebook documents ITS and Transit ITS technologies currently in use, assesses their potential to provide market research data, and presents methods for collecting and analyzing these data. Also, the guidebook provides three in-depth case studies that illustrate how ITS data have been successfully used to improve market research practices. The guide should be useful to small, medium, and large transit agencies.

Transit agencies use market research for a variety of purposes—scheduling and operations planning, long-range planning and design, performance analyses, market penetration and market segmentation analyses, and gathering data on mode choice and travel patterns, consumer perceptions, consumer preferences, pricing elasticity, customer satisfaction, market segmentation, market usage, scheduling, trip planning, supply and demand, crime mapping, and new product and service evaluations. Also, market research can show where to target resources to have the greatest impact on maintaining and increasing ridership. Because the data are used extensively throughout the major departments within transit agencies, reliable and cost-effective market research is a priority.

While transit market research is becoming more expensive, intelligent transportation systems (ITS), including Transit ITS (formerly known as advanced public transportation systems, or APTS), are transforming the way transportation and transit agencies operate. Because ITS and Transit ITS involve real-time data capture, these technologies have potential to inexpensively capture objective market information at high levels of data accuracy and completeness. Transit agencies should be prepared to capitalize on these efficiencies for transit market research. The use of these data by transit operators, transportation planners, and transit marketers presents significant opportunities for both short-term and long-term gains in transit use. In addition, transit properties that leverage objective customer information from these systems may be able to be more proactive in serving transit customers.

Currently, little information exists about the types of ITS and Transit ITS data best suited for market research or about the extent of ITS and Transit ITS data use for this purpose by transit agencies in the United States. This guidebook provides information on the technologies with the greatest potential for recovering data to support market research activity. The guidebook also addresses issues that need to be resolved to ensure easier and more effective use of data within transit organizations.

Under TCRP Project B-29, "*Transit Market Research: Leveraging ITS and Transit ITS Data,*" the research team conducted a comprehensive review of literature, practice, and findings related to ITS and Transit ITS deployments potentially related to market research opportunities. The research team collected data from a representative sample of transit agencies about known and potential uses of ITS and Transit ITS data either as substitutes for, or in conjunction with, primary market research activities. For the data collected, the research team identified the market research purpose, type of data used, the data validation process, and how data were collected and analyzed to fulfill the market research objective.

The research team conducted case studies that include a summary of the ITS and Transit ITS technologies and applicable data used within transit agencies and assess the impacts of the use of ITS and Transit ITS data on market research practices.

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SUMMARY

Leveraging ITS Data for Transit Market Research: A Practitioner's Guidebook

The transit industry is increasingly drawing on data recovered by intelligent transportation systems (ITS) technology in its commitment to delivering high quality service to its customers. As it has gained experience with advanced technologies, the industry has discovered new opportunities for using ITS data to better understand customers and markets. A large volume of customer-relevant ITS data is beginning to complement and reinforce customer information obtained from traditional research methods to provide a more comprehensive and contemporary understanding of transit markets. The technologies offering the greatest potential to support customer and market research include automatic vehicle location (AVL), automatic passenger counters (APC), mobile data terminals (MDT), electronic registering fareboxes, magnetic stripe cards, and smart cards. In addition, automated phone systems and the Web are not only providing information to customers, they are also obtaining information from customers. Nearly half of the transit properties reporting to the Federal Transit Administration's National Transit Database have now deployed these technologies.

This Guidebook has been prepared to assist market research practitioners in their efforts to use ITS data in analyzing transit customers and markets. It envisions an integrated marketing system within which research informs service development and delivery. The contributions of ITS data in the integrated marketing system are divided between two main support channels. The first channel is dedicated to supporting ongoing practices dedicated to monitoring and evaluating services delivered to or consumed by customers. Monitoring and evaluation practices focus on such questions as

What is the quality of service delivered to customers?
How many customers are using the system, when are they using it, where are their access and egress locations, and what transfers are they making?
How are customers' route or path choices related to service attributes?
How are customers responding to changes in fares, level of service, route design, or marketing and promotion?

Traditionally, analysis of these questions required manual data collection, which was a time consuming, costly, and, at best, periodic process. ITS technologies now automatically recover data to analyze these questions in a more comprehensive and timely way, at very low cost.

The second channel through which ITS data support the research process is by facilitating and leveraging traditional market research methods, such as customer surveys, market surveys, and focus groups. Passenger data recovered from ITS technologies can be used to define sampling plans, establish sampling weights or expansion factors, and determine the

best times to survey. ITS service performance data can be used to help identify times and locations for recruiting focus group participants.

Leveraging opportunities also exist in relating ITS data to survey information. For example, origin-destination (O-D) survey information can be used to validate passenger flow models estimated from farebox, fare card, and APC data. In the interim period between O-D surveys, which is often 10 years or longer, ITS data can be used to maintain contemporary estimates of passenger flows to support marketing and planning activity. In another example, information from rider satisfaction surveys can be related to operations data recovered by AVL, APCs and MDTs to assess the correspondence between riders' perceptions of the quality of their experience and the transit agency's metrics of the quality of service that was delivered to them.

The Guidebook presents case studies describing how three transit properties of varying size have capitalized on ITS data. For example, the Chicago Transit Authority (CTA) is using its smart card and APC data to develop passenger flow models for rail and bus service. It is also developing tools using other ITS data that can be used by staff throughout the agency on its intranet. TriMet has drawn on its extensive market research experience in developing customer-oriented service performance measures based on AVL and APC data. Madison Metro Transit, despite limited experience with ITS technologies, is drawing on magnetic stripe card data in developing its employer and student pass programs, which now account for half of their system's annual ridership.

Most of the ITS technologies now in operation among transit properties have been deployed over the past 10 years. The pace of deployment represents a fairly rapid and dramatic transformation for the industry. There are a number of lessons that can be learned from deployment experiences that collectively offer the potential to achieve greater benefits in leveraging ITS data for market research. An important lesson learned early is the need to plan for systems compatibility, especially among AVL, APC, MDT, and fare cards. For some properties, inadequate systems planning has meant procuring and maintaining multiple AVL systems to support other on-board technologies.

The second lesson is to plan for data validation and management. An enterprise data system must be designed to coordinate and manage the enormous volume of ITS data that are generated. There must be an assurance that the data produced by each new technology conforms to an established data model. A screening process must be developed to verify the validity of ITS data.

The third lesson is to involve data users early in the technology planning process. Otherwise, market research practitioners will be less productive using ITS data defined by others.

The fourth lesson is to recognize that new skills will be needed among market research and other staff, requiring a strategy or plan for staff recruiting, retention, and career development.

The final lesson is for senior management to recognize the need to develop a technology plan and budget for the agency that coordinates the hardware, information, and human resource infrastructures associated with the ITS technology life cycle.

CHAPTER 1

Introduction

The transit industry is now recognizing what many industries and retailers have known for a long time: to increase sales, you must understand and satisfy your customers. Transit is rapidly coming up to speed with collecting customer information and using market research to develop a customer orientation. This process requires an ongoing commitment to asking customers what they want, responding to their needs, and following up with monitoring and evaluation to ensure the agency is delivering on its promises (Cambridge Systematics 1999).

At the same time that the transit market research paradigm is evolving toward a greater customer orientation, a shift is also taking place with the implementation of ITS technologies. These technologies, whose primary purposes have been to improve transit operations, enhance convenience, and facilitate the flow of information to customers, also have the capability of recovering vast amounts of data about customers and the transit services they consume, thereby providing a rich resource for market researchers.

Several ITS technologies hold the greatest promise for recovering data that will benefit transit market research. They include AVL systems, APCs, electronic fare payment systems (EFP), automatic vehicle monitoring (AVM), and Web systems (including Web tracking software or Web logs). In addition to data collection technologies, there are also several emerging support technologies. The key support technologies include data warehousing systems, which organize and integrate data recovered from various ITS technologies, and geographic information systems (GIS), which facilitate the analysis and display of spatial data.

In the early years of its adoption in the transit industry, AVL technology was viewed as a means of providing real time vehicle status information in support of dispatching and operations management. However, the industry is beginning to realize the value of archived AVL data in the areas of performance monitoring, scheduling, and service planning (Casey 2000, 2003; Furth et al. 2006). The treatment of quality-of-service issues in the 2nd Edition of the *Transit Capacity and Quality of Service Manual* (Kittelson & Associates 2003), for example, envisions the use of archived AVL data to monitor the quality of service delivered to transit riders.

APC technology has a longer history in the transit industry. The integration of APC and AVL systems has now become commonplace, enhancing the locational referencing of passenger movement activity and thereby ensuring higher quality APC data. APC deployment is expanding rapidly, especially in medium and smaller size agencies (Volpe National Transportation Systems Center 2005), and APC data has become a valuable source of information in market research, service planning, and scheduling.

EFP technologies are evolving beyond the electronic registering fareboxes now in widespread use in the transit industry. Magnetic stripe and smart cards are being used by a growing share of transit riders. Data from card systems are highly valuable because they can identify customers and customer groups. These data offer the capability of following customers through the system and provide an opportunity to relate customers' revealed travel behavior to the attitudes and preferences they express in traditional surveys.

AVM technology recovers data on vehicles' mechanical and electrical systems. While much of this information is relevant to maintenance activities, some information (covering lift deployments, door openings, and signal priority requests) has potential value for market research and customer service use.

Transit agencies are increasingly tapping the capabilities of the Web to provide information and services to customers. In turn, Web-tracking software compiles data logs that can provide information about customers to the agency on pages viewed, navigation paths through the website, the travel itineraries queried, the real time status of vehicles serving specific locations, and other dynamic information. Similar path-tracking software exists for automated telephone systems.

The intent of this Guidebook is to show transit market researchers how ITS data can be tapped to learn more about customers and how they use the transit system. Generally, ITS data can serve market research objectives in two ways. First, the data can be used to monitor service delivery and consumption, as an ongoing activity or in a more targeted fashion (for example following changes in service and fares or after a marketing campaign). In these applications, ITS data substitute for data that have been traditionally collected by manual means. Second, ITS data can be used to enable traditional market research practices, and in these applications they complement rather that replace traditional data. The research team refers to the complementary role of ITS data as "leveraging," in that it extends or adds value to information recovered by traditional practices.

Definition and Benefits of Market Research in an ITS Environment

Market research is the systematic gathering, recording, and analyzing of data with respect to a particular market, where market refers to a specific customer group in a specific geographic area (American Marketing Association 2007). In the transit industry, this definition encompasses analysis of customer satisfaction, public opinions, market characteristics and trends; identification of potential markets; demand estimation; market segmentation; new product testing and development; advertising and promotions; and fares and pricing policies (Elmore-Yalch 1998a). Market research activities are often closely aligned with service planning in transit agencies, fare and service changes, and service performance monitoring linked to market research findings.

The most common traditional techniques for addressing market research questions in the transit industry draw on analysis of data and information from surveys, field observations, focus groups, and secondary data sources. Market research techniques used in the transit industry have been documented by Hatfield and Guseman (1978) and Retzlaff, Soucie and Biemborn (1985). The use of market research for transportation systems management has been addressed by Apogee Research (1990).

Personal observation is a market research practice that is predominately used to monitor service delivery. Observation data are collected by dedicated data collection staff or contractors, who sometimes pose as "mystery riders." Personal observation techniques include manual collection of service delivery data, such as schedule adherence, boardings, alightings, and passenger loads.

Focus group techniques are used to gather information about customers' opinions, viewpoints, and perceptions on specific topics. Structured discussions allow market researchers to explore issues within a controlled setting, with the goal of gaining a deeper understanding of customers' attitudes and preferences. Focus group techniques are valuable for exploring topics that customers may be unfamiliar with; evaluating existing services; exploring creative ideas; and narrowing options for subsequent analysis through traditional surveys.

Customer surveys provide the principal means of recovering systematic information from transit users and the general population. Surveys take a variety of forms, including onboard rider surveys, on-street intercepts, mail and telephone surveys, online surveys, and household travel diaries. Onboard surveys are used for recovering information about the users of the system and their trip information; mail and telephone surveys are best suited for regional assessment and tracking of attitudes and behaviors associated with both riders and non-riders; on-street intercepts are good for short surveys, especially those that require presentation materials; online surveys are useful for recovering specific information from customers with Internet access.

The staff and resources required to maintain a comprehensive market research program are not inconsequential. Market research is costly, and this function competes with others for scarce resources. In the transit industry it has thus been necessary to regularly demonstrate the value that market research adds to the organization (Elmore-Yalch 1998a, 1998b; Fielding 1987; Kittelson & Associates 2003; Morpace International 1999; Potts 2002). The increasing availability of ITS data in the transit industry can contribute to the business case for market research by enabling a more comprehensive integration of market research with other functions that contribute to the industry's customer service mission.

Effective transit market research does not take place in isolation. The design and execution of a comprehensive market research program depend on effective interaction with transit operations, planning, finance, human resources, and senior management. Any market research endeavor must anticipate how the research output will combine with the agency's functions, strategies, and goals to form an integrated marketing plan. Finally, monitoring and evaluation of implemented marketing plans provide important feedback information for current and future market research. Successful market research is aware of its important position within a larger agencywide marketing framework.

Fielding (1987) emphasizes that market research should be performed as an integrated function within a larger transit marketing system. Ideally, market research should inform the development of marketing plans, and the monitored effects of implemented marketing plans should feed back into the system and inform the next round of research. Despite the promise of an integrated marketing system, Fielding concludes that the critical monitoring function rarely happens, breaking down the cycle and isolating market research from service delivery. He points to the difficulty and cost of collecting reliable data as the key impediment to the monitoring function.

Figure 1-1 updates Fielding's integrated framework and locates market research within the larger marketing system when ITS data are available. By providing continuous, low-cost data, ITS fills the service monitoring gap identified by Fielding and completes the integrated marketing cycle. In the updated framework, ITS data both inform the market research program and monitor the consequences of implemented marketing plans.

Market research benefits from service delivery data as an input in the design and analysis of market research projects. The arrow from ITS data to market research in Figure 1-1 represents ITS data that have direct applications in facilitating, or leveraging, traditional market research techniques. In this context, ITS data can provide information to market researchers that helps to identify (or locate) the customer populations who are to be studied. ITS data can also contribute information needed for sampling customer populations and inferring findings from a sample to the general population. In some applications, ITS data can serve to maintain the currency of the knowledge about customers gained through traditional practices. Lastly, it can make information and insights gained from traditional practices more robust by connecting the dimensions of customer satisfaction explored through traditional practices to parallel service delivery measures documented by ITS data.

Marketing action plans typically include elements of service development and delivery (coordinated within operations and planning), promotion, and customer service. Each component benefits from the continuous monitoring function of ITS technologies, represented in Figure 1-1 by the position of ITS data as the intermediary between marketing action plan components and the monitoring and evaluation function. Within service delivery, for instance, AVL data can contribute to evaluating reliability. APC data can document how many riders are using the system. Farebox and card system data can document methods of payment and begin to identify customer segments. Event data can document phenomena that affect the quality of riders' experiences on the system. Data from the Web and automated phone systems can document how customers are obtaining information and what they are communicating back to the agency about their experiences on the system. Generally, because ITS data are collected continuously and comprehensively, quasi-experimental before and after studies can be done to evaluate the effectiveness of a marketing program. In this context ITS data validate traditional market research practices by assessing the impact of marketing action plans and informing the next cycle of market research studies.

Before the emergence ITS data, the monitoring and evaluation function of the integrated marketing system, as practiced at many transit agencies, was often resource-starved and haphazardly undertaken. In this more constrained context, marketing was often equated with promotion and customer service. Important as these functions are, they do not represent marketing as it is practiced in other industries (Cronin and Hightower 2004). Being "customer-oriented" certainly means listening when customers lodge complaints. It also means providing information that customers want and need to use the system, as well as promoting the benefits of transit as a travel option and providing products and services to facilitate choices. Fundamentally, however, a customer-oriented marketing program has to be capable of understanding customer behavior. Understanding customer behavior begins with an ability to monitor the consumption of products and determine how consumption is related to product attributes. The understanding becomes deeper

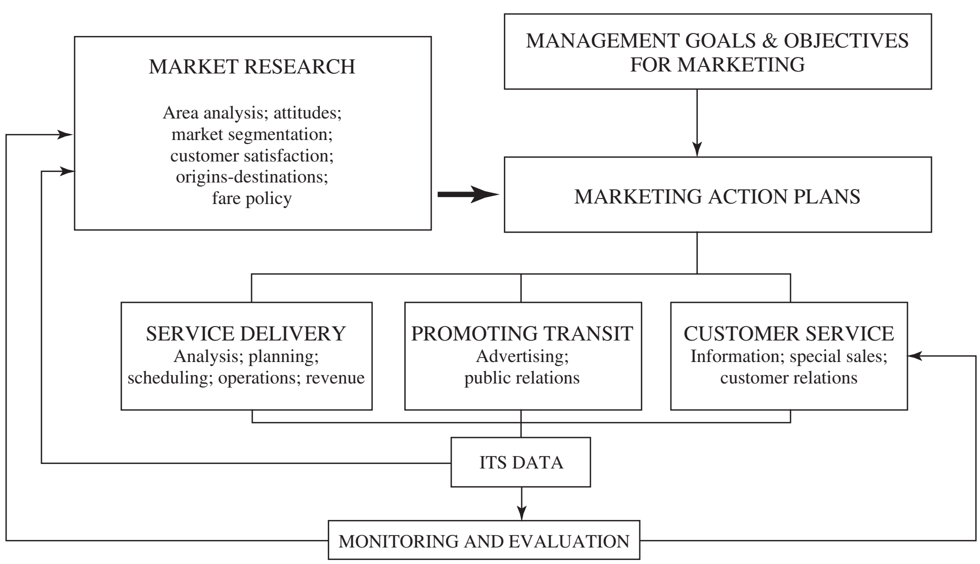

Figure 1-1. Market research in an integrated marketing system with ITS data.

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when knowledge of product-relevant values, attitudes, and preferences of customers within and across markets is gained, and that knowledge is used to guide product development and delivery. The understanding becomes complete when evidence shows that products have penetrated markets to their maximum potential.

Without the feedback information obtained from monitoring and evaluation, it is hard to know whether marketing action plans have been successful or whether market research has had any consequence. In such an environment, the legitimacy of market research cannot be firmly established. Under these conditions, there is a strong tendency for marketing to become isolated within the agency (Elmore-Yalch 1998b). Divorced from the important service delivery function, marketing then loses its strategic connection to the agency's principal product.

The promise of ITS data lies in its potential to ultimately raise the stature of transit marketing and market research programs to a level that is comparable to what exists in other industries. Its direct contribution to market research practices and its contribution to monitoring and evaluating service delivery reinforce elements of the integrated marketing system that have been underdeveloped or missing altogether in many transit agencies.

The transit industry's transition to greater utilization of ITS data for market research has not been seamless nor without challenges. Properties have encountered system design, data management, and human resource issues in their efforts to fold ITS data into their market research and other functions (FTA 2005; ITS Joint Program Office 1999a, 1999b, 2000, and 2001; TCRP 2001). Thanks largely to the growing exchange of information and experiences—both formally and informally organized—lessons are being learned at each stage of the ITS life cycle and the magnitude of many of the challenges encountered earlier is diminishing.

What the Guidebook Covers

This Guidebook will show transit market researchers how ITS data can be used to support their efforts to gain a better understanding of customers and their travel on the system. In some applications, ITS offers a superior and cost-effective substitute to data that market research staff have traditionally collected manually to monitor customer activity. In other more advanced market research applications that seek to gain an understanding of customers' attitudes, preferences, and behavior, ITS data can be used to leverage the practices that have traditionally been used to recover information.

Chapter 2 of the Guidebook begins with a summary of the market research practices that are commonly employed in the transit industry. The chapter continues with a description of data that are recovered by the technologies of interest in this study. The chapter concludes with a discussion of both the advantages and the limitations that should be recognized in efforts to relate data and information from traditional market research applications and data from ITS technologies.

Chapter 3 of the Guidebook presents an inventory of possible uses of ITS data in market research applications. The applications are separated into two general categories. The first, defined as service delivery monitoring, presents applications in which ITS data are used to complement traditional practices. The second category covers leveraging opportunities, where ITS data are used in direct conjunction with traditional market research applications.

Successful experiences linking ITS data with market research practices in the transit industry are commonly grounded in four key dimensions. First, an enterprise data system must be in place that is capable of processing, integrating, and storing ITS data, allowing for easy accessibility. Second, analysis and reporting tools that draw on ITS data must be available to market researchers. Third, the data management and market research enterprises must be adequately staffed with people possessing the skills needed to perform in an advanced data environment. Fourth, because ITS data are used agency-wide, coordination across agency functions has become more important. Both staffing and coordination needs can be hard to achieve without management support. These subjects are covered in Chapter 4.

The transit industry's progress toward the goal of gaining a better understanding of its customers and markets depends on its ability to learn from its experiences. Chapter 5 summarizes issues that have been commonly encountered in the industry's transition to using ITS data for market research. The nearly 20-year experience of the transit industry with advanced technologies has yielded many lessons that properties newly moving into the ITS arena or upgrading existing systems would benefit from knowing.

A substantial amount of the information reported in this Guidebook was obtained from case studies of three properties—the CTA, City of Madison Metro Transit, and TriMet. These case studies are appended to the Guidebook (Appendices A, B, and C, respectively). The case studies provide worthy reading independent of the main text in that they present coherent stories that illustrate how each property achieved success in drawing ITS data into its market research practices.

CHAPTER 2

Introduction to Market Research and ITS Data

Understanding Customers: Traditional Market Research Techniques

Market researchers in the transit industry collect information about their customers and the traveling public in a variety of ways. The most commonly used techniques for recovering information include intercept surveys of persons riding the system or at given locations, telephone and mail surveys of area populations, field observations (recording the delivery and consumption of service), and focus groups.

One way of clarifying the distinctions among the various market research techniques is to delineate their key features with respect to the population(s) targeted, the information that is recovered, and the questions analyzed from the information recovered. This is illustrated in the typology presented in Figure 2-1. Each technique is defined by a distinct target population, the specific kinds of information sought, and the research questions that are analyzed. In the practice of market research, it is probably more logical to rearrange the columns of the typology to correspond with the research process. This process usually begins with a set of questions (e.g., "Who is using our system?"). These questions then determine the identity of the subject population and the information that will be sought from them or, rather, their sampled representatives.

Questions driving the research process can range from simple and direct to complex and multifaceted. At one end, for example, is the singular, direct question "How many people are riding our system?" The "analysis" of this question requires recovering information about users of the system. The type of information needed is simple: counts of boardings and alightings from a representative sample of times/locations in the system. Among the range of approaches listed in Figure 2-1, the technique that is best suited to recover customer count information at lowest cost or least effort would be a field observation method. This would involve assigning ride checker staff to record boardings and alightings on sampled trips or trip segments. The analysis of the sample data would be limited to expanding the sample counts to infer the system's total ridership.

Much more complex sets of questions reside at the other end of the market research spectrum. For example, the question "How do riders on our system differ from non-riders?" indicates that the target group is the general population of travelers residing in the service area. The only way to recover the necessary information from this group is through a mail or telephone survey. The information that must be recovered is determined by the desired scope and depth of understanding of the distinctions between the two groups. Usually, a threshold information set would cover frequency of use, age, sex, race, ethnicity, income, residence and work locations (if employed), and vehicle ownership. This information set would provide the necessary data for market segmentation analysis along traditional lines. More advanced approaches to market segmentation analysis, however, seek to further distinguish riders and non-riders along attitude, opinion, and preference dimensions. Doing so requires recovery of scaled response information on attitudes, preferences, perceptions, and opinions on a range of topics known to influence persons' travel choices. Incorporating this information into the analysis not only provides an opportunity to gain a greater depth of understanding of the distinctions between riders and non-riders, it also allows for further identification of subgroups within the two populations.

Identifying such subgroups holds great strategic importance in transit marketing programs. Among transit rider subgroups, for instance, one can usually identify a segment whose members would rather not be using the system. Knowing why this is the case is the first step toward taking action to retaining riders who may be on the verge of leaving the system. Some members of this group may prefer another means of travel, but cannot presently afford to act on that preference. Should their incomes increase, there may be little that a marketing campaign can do

Approach	Target Group(s)	Information Obtained	Questions Analyzed
Intercept Surveys: • On-board • On-street	Riders Non-Riders	Personal Demographics Travel Characteristics Fare Payment Used Attitudes, Preferences, Perceptions & Opinions	Who is using our system? How often do they ride? Where are riders coming from and where are they going? Why are they traveling? How are they paying? What are their travel options & preferences? How satisfied are they with their experience on the system? What do they think about a possible change?
Telephone & Mail Surveys	Riders & Non-riders	Household Demographics Travel Characteristics Attitudes, Preferences, Perceptions & Opinions	How do riders differ from non-riders? How are travel market segments defined? What should we do to retain & attract riders? How would riders and/or non-riders respond to a service change?
Field Observation	Riders Agency Employees System Infrastructure	System Usage Service Delivery Customer Service Infrastructure Condition	How many customers are being served? Is service reliable and on time? How easy is it for riders to use the system? How are riders treated? What are conditions like on the system?
Focus Groups	Target Group Varies by Topic	Perceptions, Opinions, Attitudes & Preferences	How would riders and/or non-riders respond to new ways of doing things? What is really important to riders and/or non-riders? What should we do to make the system better?

Figure 2-1. Typology of transit market research approaches.

to sway their decision to leave. Other members, however, may be uncomfortable or dissatisfied with their experiences on the system, and getting to the bottom of their perceptions presents an opportunity to take corrective action that will mitigate problems they encounter or perceive.

In contrast with rider segments, analysis of attitudes and preferences among non-riders often identifies a subgroup whose members express very favorable opinions, perceptions, attitudes, and preferences toward transit as a travel option, but have not followed through in their actual travel mode choices. For some, the underlying reason may be simple: they lack reasonable access to service. Analysis can then shift to the question of whether this group is sufficiently large and geographically concentrated enough to be cost-effectively served. For others, access may be adequate, but they lack a compelling reason to change their travel choices. Analysis of their opinions, attitudes, and preferences may reveal the values that may motivate a change in their choices. This group would be receptive to marketing initiatives promoting transit that resonate with these values.

These two subgroups represent what may be the most important latent markets in the transit industry. Their affiliation with transit lies very close to the choice point with other modes. To build a high ridership system it is necessary to identify these groups and understand what they want. Their allegiance as riders is, at the same time, most readily gained in a successful market development program and most easily lost when market researchers ignore them.

In some instances, rather than initiating the market research process with a set of questions, analysts turn to a target population for their views on how questions should be defined and interpreted. This can be motivated by an interest in gaining a deeper understanding of issues that are believed to be important to customers, or to explore customer reactions to new ideas and issues. For example, regarding the former, satisfaction surveys often reveal that service reliability and safety and security are important issues in customers' minds. Yet, it is also known that riders rarely consult schedules, and crime statistics suggest that the system is commonly safe and secure. Thus it is apparent that riders are expressing perceptions or opinions that may not be reflected in measures such as schedule adherence or crime incidence.

Probing issues or questions through focus groups may provide better definition of customer perceptions. For example, riders' concern with "reliability" may, upon deeper consideration, be revealed to be grounded in the uncertainty they experience wondering when the next vehicle will be arriving. Alternatively, it may turn out to be a reaction to seeing platoons of vehicles on high frequency routes that are failing to maintain scheduled headways. Probing concerns about "safety and security" may reveal that riders are uncomfortable with unfamiliar places, or when riding with others who are different from them. In both examples, getting to the bottom of perceptions can help to identify actions that would improve riders' satisfaction with service. Posting schedules at stops or, in an ITS world, posting the next vehicle's expected arrival in real time may be the best action that can be taken to improve riders' dissatisfaction with reliability. Providing information at stops and adding various treatments on vehicles or along riders' common access and

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egress paths may be what is needed to address concerns with safety and security.

Focus groups can provide valuable information in the consideration of new practices or systems. In the area of fare payment, for example, transit providers can turn to focus groups to gain insight on customer perceptions and opinions of a new fare option or a new system for fare payment. Considerable time and resource investments are at stake in each case, and focus group analysis can serve to reduce investment risk by gauging market acceptance.

Some of the most elementary yet critical market research questions are analyzed from information gathered through field observation techniques. Some of these questions focus on vehicle operators who, in delivering service, represent the principal contact between a transit agency and its customers. Do they operate their vehicles with customers' safety and comfort in mind? Do they treat riders with respect and respond to their questions? Do they announce stops? Do they provide assistance when requested to riders with disabilities? The information required to evaluate these questions is commonly recovered by "mystery shoppers," who pose as riders and record observations on riders' experiences. The knowledge gained from evaluating this information can help to identify areas needing greater emphasis in ongoing training programs.

Operators themselves and other field personnel have traditionally served as sources of information on conditions in the system affecting riders' travel experiences. Operators are relied on to report problems with the state of repair and cleanliness of vehicles, stops and stations, potential hazards that riders and others may encounter, and situations that threaten rider safety or the safe operation of vehicles. More informally, vehicle operators have also commonly reported back their assessment of the adequacy of schedules, the layout of routes, and the location of stops.

Field observation approaches also include recovery of basic service delivery data by staff "ride checkers." These data include boarding, alighting, and load counts; vehicle running times; and schedule, headway, and timed transfer adherence. The scope and frequency of ride checker data recovery are defined, at a minimum, by the annual reporting requirements of the Federal Transit Administration's (FTA) National Transit Database (NTD) program. Beyond NTD reporting, transit agencies commonly seek more extensive recovery of service delivery data to support service planning, scheduling, and operations management needs.

Intercept surveys, fielded either on-board vehicles or at specific locations, are the workhorses of most transit market research programs. Much of what a transit agency understands about its customers is learned through analysis of intercept survey data. On-board surveys can provide demographic profiles of riders on the system; information on the purposes of their trips; where their trips begin and end; the path of their travel through the system; how they pay for service; their dependence on transit to meet their travel needs; their preference for transit in relation to other modes; and their satisfaction with the services provided. On-street surveys recover information about how people travel to or from given locations; and their perceptions, preferences, and opinions about location, program, or product-related attributes of service delivery.

Information from O-D surveys provides a foundation for the design and delivery of transit service to a community. Unless more detailed or extensive travel information is being sought, O-D surveys are designed to be fielded on transit vehicles. An example of an on-board O-D survey instrument is shown in Figure 2-2. This instrument was fielded on TriMet's bus, light rail, and streetcar system in 2005. The figure provides a useful illustration of several features of an on-board survey. First, it is designed to recover as much information as can be reasonably expected during the course of a typical rider's time on a vehicle. Second, despite the response time limitation, the scope of information sought in the instrument nevertheless extends beyond that needed to identify trip characteristics to include limited examples of most other types of information recovered in on-board surveys. This additional information allows researchers not only to document travel patterns occurring on the system, but to relate these patterns to personal characteristics.

The typology of transit market research approaches presented in this section does not include information that flows into the agency from customer-initiated contacts by telephone or the Web. Information from these contacts includes commendations, suggestions, and complaints, as well as travel queries recorded by trip planning software and real time vehicle arrival queries. Logs of the information obtained from customer-initiated contacts are usually maintained for tracking and analysis. In particular, the incidence of commendations and complaints is usually included among the system performance indicators that are closely tracked by senior management.

What distinguishes customer-initiated information from the information recovered by the approaches identified in the market research typology is the ability of the latter to support inferences from a limited number of observations to a definable population. For surveys and field observation approaches, the ability to make such inferences is ensured by following statistical sampling plans. For focus groups, it is ensured through careful screening of participants to represent an intended audience. Alternatively, inferences are difficult, if not impossible to make from customer-initiated data. For example, it is hard to know what population is being represented by persons querying trip planning software. Thus, it is very unlikely that a trip table "inferred" from trip planning

TRI MET

RIDERSHIP SURVEY

*To help us plan better service, please tell us about your **ONE-WAY trip**. **Fill out this form even if you have already received one before, or rarely use TriMet or the Portland Streetcar.** When finished, place the form in the envelope near the door, or you may return it by postage-paid mail.*

This One-Way Trip

1. Where did you come from on this trip? *(check one best answer)*
- ☐ 1 Home ☐ 5 Personal business ☐ 8 Visiting friends/relatives
- ☐ 2 Work ☐ 6 Shopping ☐ 9 Medical appointment
- ☐ 3 School ☐ 7 Other: ______
- ☐ 4 Recreation: ______

2. Where was that located ? *(see question 1)*
*(Complete address & city **OR** street/cross street & city **OR** landmark)*
(circle one) NE SE NW SW
Street: N S E W ______
Nearest Cross Street: ______
City: ______ Zip Code______

3. How did you get to the stop/station where you got on this bus/MAX/Streetcar? *(check one best answer)*
- ☐ 1 Walk ______# blocks ☐ 6 Transferred from Streetcar
- ☐ 2 Drove ☐ 7 Dropped off by someone
- ☐ 3 Transferred from bus#: ___ ☐ 8 Other: ______
- ☐ 5 Transferred from MAX

4. Where was that stop/station located?

______
(Street/cross street & city)

5. At what stop/station will you get off this bus/MAX/Streetcar?

______
(Street/cross street & city)

6. Where are you going on this trip? *(check one best answer)*
- ☐ 1 Home ☐ 5 Personal business ☐ 8 Visiting friends/relatives
- ☐ 2 Work ☐ 6 Shopping ☐ 9 Medical appointment
- ☐ 3 School ☐ 7 Other: ______
- ☐ 4 Recreation: ______

7. Where is that located ? *(see question 6)*
*(Complete address & city **OR** street/cross street & city **OR** landmark)*
(circle one) NE SE NW SW
Street: N S E W ______
Nearest Cross Street: ______
City: ______ Zip Code______

8. How will you get to that location from this bus/MAX/Streetcar? *(check one best answer)*
- ☐ 1 Walk ______# blocks ☐ 5 Transfer to Streetcar
- ☐ 2 Drive ☐ 6 Be picked up by someone
- ☐ 3 Transfer to bus#: ___ ☐ 7 Other: ______
- ☐ 4 Transfer to MAX

10. Did you have to transfer to or from a different bus/ MAX/Streetcar to make this trip in one direction?
☐ 1 No ☐ 2 Yes→ *If yes*, how many times? ______

11. Did your employer or school pay for any portion of your fare?
☐ 1 No ☐ 2 Yes

12. What is the major reason you are using the bus/MAX/ Streetcar for this one-way trip? *(check one best answer)*
- ☐ 1 I do have a car but prefer to use TriMet.
- ☐ 2 I don't have a car because I prefer to use TriMet.
- ☐ 3 I don't have a car available for me to use.
- ☐ 4 I don't drive or don't know how to drive.

13. If transit service were not available, how would you make this kind of trip? *(check one best answer)*
- ☐ 1 Use a car ☐ 5 Bicycle
- ☐ 2 Walk ☐ 6 I would not make this trip
- ☐ 3 Ride with a friend ☐ 7 Other: ______
- ☐ 4 Use a taxi

About You

14. How many trips have you taken on a TriMet bus/MAX/ streetcar in the last month? *(count each direction as one trip)*
- ☐ 1 0 or 1 ☐ 3 7 to 12 ☐ 5 30 or more
- ☐ 2 2 to 6 ☐ 4 13 to 29

15. What is your home zip code? ______

16. What year were you born? 19______

17. Gender ☐ 1 Male ☐ 2 Female

18. Are you: *(check one)*
- ☐ 1 Asian/Pacific Islander ☐ 4 Hispanic/Latino
- ☐ 2 African-American/Black ☐ 5 Native American Indian
- ☐ 3 Caucasian/White ☐ 6 Other: ______

19. What was your total annual household income before taxes in 2004? *(check one)*
- ☐ 1 Under $10,000 ☐ 6 $50,000 to $59,999
- ☐ 2 $10,000 to $19,999 ☐ 7 $60,000 to $69,999
- ☐ 3 $20,000 to $29,999 ☐ 8 $70,000 or more
- ☐ 4 $30,000 to $39,999 ☐ 9 Don't know
- ☐ 5 $40,000 to $49,999

Your Opinion of This Trip

20. Please read the following statements and answer using the 5-point rating scale. *(Circle 1 answer for each statement.)*

	Poor				Excellent
a) Cleanliness inside vehicle	1	2	3	4	5
b) Safety while on-board	1	2	3	4	5
c) Reliability of service	1	2	3	4	5
d) Frequency of service	1	2	3	4	5
e) Over-crowding	1	2	3	4	5
f) Cleanliness @ stop	1	2	3	4	5
g) Safety while waiting @ stop	1	2	3	4	5

9. How did you pay for this trip? *(check one)*
- ☐ 01 Employee ID with TriMet sticker ☐ 02 College ID with TriMet sticker ☐ 03 Fareless Square (free) ☐ 04 Other: ______
- ☐ 05 **Regular TriMet or Streetcar fare** --> please select from below
- ☐ 06 **Regular C-TRAN fare**--> please select category closest to your fare from below

9a. Regular TriMet/Streetcar/C-TRAN fare – please check one.

	CASH 2	TICKET (BOOK OF 10) 3	MONTH PASS 4	½ MONTH PASS 5	ANNUAL PASS 6
Adult All-Zone	07 ☐ $ 1.70	07 ☐ $16.50	07 ☐ $62.00	07 ☐ $31.00	07 ☐ $682.00
Adult 2-Zone	08 ☐ $ 1.40	08 ☐ $13.50	08 ☐ $51.00	08 ☐ $25.50	08 ☐ $561.00
Adult 1-Zone		09 ☐ $13.00			
Day ticket		10 ☐ $ 3.50			
Honored Citizen/STAR	11 ☐ $ .65	11 ☐ $ 6.00	11 ☐ $17.00	11 ☐ $ 8.50	11 ☐ $187.00
Youth/Student	12 ☐ $ 1.10	12 ☐ $10.50	12 ☐ $17.00	12 ☐ $ 8.50	
Streetcar					13 ☐ $ 75.00

Figure 2-2. TriMet origin-destination survey instrument.

software logs would correspond to one inferred from an O-D survey. Likewise, "inferences" from customer complaints, which often refer to a person's unpleasant encounter with an operator, are unlikely to correspond to riders' assessment of their treatment by operators from a customer satisfaction survey.

Subsequent sections of this report include the use of ITS data from customer-initiated contacts. It should be noted that applications drawing on such data mainly support customer service and human resource rather than market research functions.

Inventory of ITS Data for Market Research

Deployment

The transit industry's use of ITS data for market research is conditioned by the extent of deployment of the respective technologies. The deployment status of advanced public transportation technologies has been systematically tracked over time by the U.S. DOT's Volpe National Transportation Systems Center. The Volpe Center's most recent report documents ITS deployment in 2004 (Volpe Center 2005). Data on ITS deployment status in 2004 were recovered by a survey of 516 transit properties that report information to the NTD. There were 327 responses to the survey. While the deployment status of advanced technologies among non-respondents is unknown, it is reasonable to assume that properties with operational or planned technologies were more likely to respond to the Volpe Center survey than those without the technologies.

Deployment information from the 2005 Volpe Center report is presented in Table 2-1 for the technologies of interest to this Guidebook. Information in the table is presented for 2004 and 1995, with the latter being the year covered by the Volpe Center's first deployment survey. For AVL, the number of properties with operational systems grew from 22 in 1995 to 157 in 2004, a 614% increase. Adding planned deployments, the number of AVL properties grew from 86 in 1995 to 257 in 2004, an increase of 199%. Under the limiting assumption that none of the non-responding properties had or were planning to deploy an AVL system, the corresponding industry penetration rates for this technology in 2004 were 30.4% (operational) and 49.8% (operational plus planned).

The deployment of APC systems in the transit industry has been more limited than AVL deployment. Only 11 properties reported operational APC systems in 1995, and the growth to 75 properties in 2004 resulted in an industry penetration rate just under half the corresponding AVL rate. Adding planned APC deployments yields totals of 32 properties in 1995 and 129 properties in 2004, with industry penetration of 25%.

Departing from previous surveys, the Volpe Center did not report fleet coverage information for vehicle-related technologies in its 2005 report. Earlier reports indicate that AVL and fare payment technologies are commonly deployed fleetwide, while APC systems are not. A general "rule-of-thumb" in the industry is that 15% fleet coverage is the minimum necessary for APCs to satisfy NTD reporting requirements. Anecdotal evidence suggests that properties with APCs are increasingly deploying the systems well beyond the rule-of-thumb threshold in order to support internal reporting and analysis needs.

Coverage of electronic fare payment technologies in the Volpe Center report is limited to magnetic stripe and smart card systems. In 2004, there were 159 properties with operational card systems, up from 22 properties in 1995. Adding planned systems increases the respective totals to 65 and 293.

Table 2-1. ITS deployment in the transit industry, 1995–2004.

	AVL	APC	Electronic Fare P'mt	Automated Transit Info.
1995				
Operational	22	11	22	48
Operational + Planned	86	32	65	93
2004				
Operational	157	75	159	488
Operational + Planned	257	129	293	512
Percentage Change, 1995-2004				
Operational	614%	582%	623%	917%
Operational + Planned	199%	303%	351%	451%
Industry Penetration, 2004				
Operational	30.4%	14.5%	30.8%	94.6%
Operational + Planned	49.8%	25.0%	56.8%	99.2%
Properties Surveyed, 2004	516	516	516	516

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The industry penetration rates for electronic fare payment systems are comparable to the rates for AVL systems.

Automated transit information technologies are defined as ". . . systems that provide information to the public, without human intervention . . ." (Volpe Center 2005: 122). The media through which information is provided include the Web, automated telephone systems, automated voice annunciation systems (AVA), signboards, cell phones, pagers, and personal digital assistants. The types of information provided include schedules and fares, trip plans, and real time vehicle arrival times. The deployment data on this collection of technologies indicate that survey staff was able to recover information about virtually all non-responding properties, most likely by visiting the properties' websites and calling their phone systems. In 2004, 488 operational and 512 operational plus planned systems were identified, compared to 48 and 93, respectively, in 1995. The 2004 figures indicated that the penetration level in the industry is near-complete.

In addition to the technologies listed in Table 2-1, the Volpe Center began reporting of the deployment of mobile data terminals in its 2002 survey. When installed on transit vehicles and integrated with AVL systems, mobile data terminals can record pre-programmed events when operators press a key. There are a number of conceivable events whose documentation would provide useful information to market researchers. The survey reported 115 transit properties with operational mobile data terminals and 137 additional properties with planned deployments in 2004. This corresponds with industry penetration estimates of 22.3% (operational) and 48.8% (operational plus planned).

There are a number of general conclusions that can be drawn from the information in Table 2-1 and from closer inspection of property-level data provided in the series of Volpe Center deployment reports:

- The pace of technology deployment over the 10-year period has been rapid, suggesting parallel transformations in data archiving infrastructure, data reporting and analysis practices, staffing needs, and skill requirements.
- ITS deployment was initially concentrated among larger properties and later spread to smaller properties. Current deployment levels are still higher among larger properties. Two implications follow from these observations: (1) there has been an opportunity for smaller properties to learn from the ITS deployment experiences of larger properties, through peer exchange and other means of communication and (2) if industry penetration measures were based on the number of customers affected rather than on properties, the extent and impact of deployment would be much greater than indicated in Table 2-1.
- Among electronic fare technology deployments and planned deployments over the decade, smart cards have become increasingly favored over magnetic stripe cards. Especially when registered, smart cards are capable of recovering more information about riders and their use of the system.
- The deployment of APCs has not been as extensive as the other technologies covered in Table 2-1, yet the passenger counts provided by these systems hold great potential for leveraging traditional market research applications.

ITS Data Inventory

The ITS technologies recovering data for market research can be grouped into two categories. The first includes systems that are installed on vehicles, including AVL, AVM, MDTs, and control heads, APC, magnetic and smart card readers, and electronic registering fareboxes. The second category includes systems supporting customer service, including ticket vending machines, automated phone systems, and the Web. Traffic counting systems are also included in the second category.

Data elements recovered from on-board systems are presented in Figure 2-3. The role of AVL systems in recording time and location information is central to the viability of other on-board systems, in addition to its independent usefulness. When integrated with AVL, the data recorded by the other on-board systems become identified with respect to where and when a specific event occurred. With systems integration, the records generated through AVL also serve as the basis for aggregating other on-board data, from unique events that are recorded at specific locations and times, to summaries at higher levels, such as route and system (spatially) and hour and month (temporally).

The integration of AVL with other on-board technologies has been problematic, especially for properties that acquired on-board systems over time in a piecemeal approach (Casey 2000). Casey pointed out that the complex proprietary software provided with the early systems hampered integration efforts, as did each property's desire to customize a given system to meet its specific needs. Integration problems have been serious enough in some cases to require installing multiple AVL units on a vehicle, with each dedicated to providing time-location referencing to one or several on-board systems.

AVL integration with other on-board systems has improved, following the development of the "smart bus" concept (Furth et al. 2006). The concept is organized around use of a vehicle logic unit for storing data recovered from on-board systems. On-board systems are now manufactured to comply with the J1708 integration standards used in most AVL systems (Society of Automotive Engineers 1993, 1996).

Focusing on AVL independent of the other systems, the most useful data for market researchers are the time-location

Automatic Vehicle Location
1. Date & time
2. Vehicle ID
3. Route ID
4. Trip ID
5. Operator ID
6. Location (latitude & longitude, Stop ID)
7. Direction
8. Arrive Time
9. Depart Time
10. Speed (average or maximum, from previous location)

Automatic Vehicle Monitoring
1. Door open & close
2. Lift deployment
3. Signal priority request

Mobile Data Terminal/Vehicle Control Head
1. Event Code (fare evasion, pass up/overload, security issue, etc.)

Automatic Passenger Counter
1. Boardings
2. Alightings
3. Load

Electronic Farebox
1. Transaction ID (if transaction-based)
2. Transaction Type (ticket/token/cash)
3. Transaction Amount
4. Ridership (operator initiated)
5. Event (operator initiated, e.g., fare evasion, lift use, pass use, transfer use, etc.)

Magnetic Stripe Card (Reader)
1. Card ID
2. Card affiliation (when registered)
3. Transaction ID
4. Transaction Amount

Smart Card (Reader)
1. Card ID
2. Person ID (when registered)
3. Transaction ID
4. Transaction Amount

Figure 2-3. Inventory of ITS data for transit market research: on-vehicle systems.

vehicle status data. At the lowest level of aggregation these data are collected at stops and route origins and destinations. Aggregating the time data over all route locations yields a vehicle's actual running time for a given trip. Analysis of the pattern of running times for all trips for specified time periods reveals typical running times and the variability of running times for a route, both of which contribute important information to the schedule writing process (Levinson 1991).

Time-location data recovered by AVL systems can also be used to assess deviations in the actual delivery of service relative to the schedule. Analyses of such deviations across time points at the route and system level are the basis for reporting on-time performance. The general practice in the transit industry has been to define service as being "on time" when departures from time points are no more than 5 min. late or 1 min. early (Bates 1986).

The pattern of depart times recorded by AVL for successive vehicles can also be compared against the scheduled headways to assess the degree of regularity in the service that is delivered to customers. Especially in frequent service situations, a deterioration in regularity results in "bus bunching," which leads to longer waits for riders, a higher incidence of crowding on vehicles, and a loss of effective service capacity for the transit agency. The ability to know where and when such problems occur facilitates the operations control process (Strathman et al. 2003). For some properties, the additional waiting time resulting from bus bunching has been standardized into performance measures that are reported to senior management (see the CTA and TriMet case studies, Appendices A and C, respectively).

AVL systems also record the location status of vehicles at specified time intervals (ranging from 30 to 90 s). These are referred to as poll data. Poll data are transmitted over the vehicle's radio system to the dispatching center. In addition to supporting dispatch functions, AVL poll data are used in real time to support software that broadcasts vehicle arrival time estimates through an agency's website or automated phone system. While real time use of AVL poll data has benefited dispatchers and customers, archived poll data are of limited usefulness to market researchers because they cannot be easily

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joined with other ITS data (given the absence of common locational references).

By counting boardings and alightings, and calculating passenger loads, APC systems provide important data to market researchers and service planners. These passenger data, compiled at the stop, route, and system levels, establish the sampling frames for rider surveys and provide the expansion factors needed to infer survey results to the riding population. The integration of APC with AVL systems has greatly improved the quality of passenger count data. Prior to AVL, passenger count data from APCs were related to stops by inferring location from time and odometer stamps on the data records, a clumsy process that screened out much of the data recovered (Strathman and Hopper 1991).

AVM technology recovers data on a vehicle's mechanical and electrical systems. While AVM data primarily support maintenance functions, they are sometimes useful for market research. AVM data on lift deployments, for example, document where riders with more serious mobility impairments access the system, supporting surveys of this special population. AVM systems also record the transmission of signal priority requests when this function exists. These data could be coordinated with corresponding signal system data to assess time savings for riders.

MDTs and control heads allow operators to record predefined events by pressing an icon or button. Conceivably, the range of "events" that affect customers' riding experience is extensive. These systems are capable of recording when and where such events occur. Event data commonly recovered by these devices include overloads and pass-ups, safety and security incidents, fare evasions, medical emergencies, and breakdowns (see the TriMet case study in Appendix C).

Electronic registering fareboxes record fare transactions data, including fare type and transaction amount. Fareboxes that are equipped with keypads also allow operators to record the fare media used and other predefined events (as described for MDTs and control heads).

Among the advanced technology systems covered in Figure 2-3, electronic registering fareboxes have often been the first to be installed on a transit property's vehicles. When AVL systems were subsequently acquired, their integration with existing fareboxes was sometimes not feasible or was not pursued. Without AVL integration, farebox data are defined by vehicle and time stamps, resulting in similar location referencing problems experienced by APC systems in the pre-AVL days. Where electronic farebox and AVL systems have not been integrated, some effort has been made to identify transaction locations by "matching" farebox and AVL time stamps (Cui 2006).

Magnetic stripe and smart card systems recover fare transactions data of the cardholders. For each transaction, magnetic card systems record the identity of the card and the transaction amount. Magnetic stripe card IDs can be registered, making the transactions of defined groups identifiable. For employer and university/school pass programs, this feature allows reliable documentation of usage and supports program development efforts (see the City of Madison Metro Transit case study in Appendix B). Smart cards have stored and recharge value capability and can be registered to individual users in connection with personal accounts. Thus the transaction data from smart card systems can identify individuals when they are registered.

Through integration with AVL systems, the transactions data for smart and magnetic card systems typically identify riders' boarding locations. Analysis of the time sequence of transactions, however, appears to be fairly successful in inferring riders' alighting locations (Rahbee and Czerwinski 2002). Similarly, when electronic fareboxes are integrated with AVL systems, summary totals for exit locations have been successfully inferred from entry location totals (Navick and Furth 2002).

Data elements for the remaining technologies covered in this Guidebook are presented in Figure 2-4. Data from ticket vending machines include each machine's location, the date and time of each transaction, the number and type of fare items purchased, the price per item, the total value of each transaction, the method of payment; and the status of the transaction.

Web tracking software documents characteristics of Internet contacts, including the date, time, and duration of each visit; the entry page, the page path through the site and exit page; and the identification of the referring website. For websites that broadcast vehicle arrivals in real time, tracking software record the route and stop location selected and the time of the request. For websites with trip planning software, tracking data cover the requests related to time of travel, origin and destination locations, preferred travel options (e.g., shortest path or time, fewest transfers), and the final travel itinerary. Most websites include features that allow customers to communicate commendations, suggestions, and complaints to the agency. In responding to these communications, customer service staff usually documents characteristics of the communication (e.g., type, date, time, route, location, and vehicle/operator identification, where possible).

Tracking software for automated telephone systems document the characteristics of each call received, including the date, time, and duration of the call; the routing of the call through the system; and the origin of the call. Similar to the Web, for phone systems with trip planning and real time vehicle arrival services, tracking software documents characteristics of the information requested. Documentation of customer communication of commendations, requests, and complaints via the phone system also occurs in a similar fashion.

Ticket Vending Machines (TVM)
1. TVM ID
2. TVM Location (latitude/longitude)
3. Transaction Date and Time
4. Article Purchased (e.g., Adult All Zone pass, Youth/Student ticket, etc.)
5. Number of Article Units Purchased
6. Price per Article Unit
7. Type of Purchase (cash, credit, etc.)
8. Total Amount of Sale
9. Transaction Status (complete, cancelled, etc.)
10. Transaction Characteristics (credit card number, expiry date, service host identifier, etc.)

Website Tracking Software
1. Date and Time of Visit
2. Duration of Visit
3. Pages Viewed
4. Entry Page
5. Exit Page
6. Path Through Site
7. Referrer (outside site referring visitor to host website)
8. Route Selected (for schedule or real time information queries)
9. Stop (for real time information requests)
10. Origin/Destination/Time/Path (for trip planning queries)
11. Communication Received (e.g., commendation/suggestion/complaint)
12. Files Downloaded

Automated Telephone Systems
1. Call ID
2. Date and Time of Call
3. Duration of Call
4. Number Called
5. Caller ID
6. Call Abandoned
7. Call Routing (e.g. trip planning, real time info., complaints, lost and found)

Traffic Counters (Loop Detectors)
1. Date and Time
2. Location (latitude/longitude, street/highway name; jurisdiction)
3. Direction
4. Vehicle Count
5. Vehicle Classification
6. Speed
7. Occupancy

Figure 2-4. Inventory of ITS data for transit market research: other systems.

Traffic loop detectors are the final technology given in Figure 2-4. The data recorded by loop detectors include location, direction of traffic, date, and time; and vehicle classification, count, speed, and occupancy for a defined time interval.

Benefits and Limitations of Combining Traditional and ITS Data

While it may be tempting to contrast the "anonymous customers" represented in ITS data with the "identified customers" in traditional market research data, such a dichotomy masks the differentiation among ITS technologies in their ability to define customers. It is true that ITS data cannot capture customers' stated attitudes, opinions, perceptions, and preferences, the core information sought in traditional market research. At the same time, if individually stated preferences occupy the core of the market research paradigm, then ITS data form rings of highly useful information around the core. Much of this information would otherwise be gathered only by using more costly and irregular manual collection techniques, if at all. Some ITS data offer entirely new sources of information or new data combinations. Furthermore, the layers of data around the core of traditional market research can improve understanding by linking customer perceptions and attitudes to extended data from ITS technologies. Finally, ITS data can serve an enabling role by assisting the collection and analysis of data gathered using traditional techniques.

Figure 2-5 displays the range of ITS technologies and their respective functions, applications, and resolutions related to the primary objectives of market research. As one moves from the periphery toward the center of the figure, the "customer resolution" improves; that is, the characteristics and travel activities of specific customers and customer groups become increasingly identifiable. At the center of the diagram is the highest level of customer resolution, representing the traditional market research goal of uncovering customers' preferences and perceptions.

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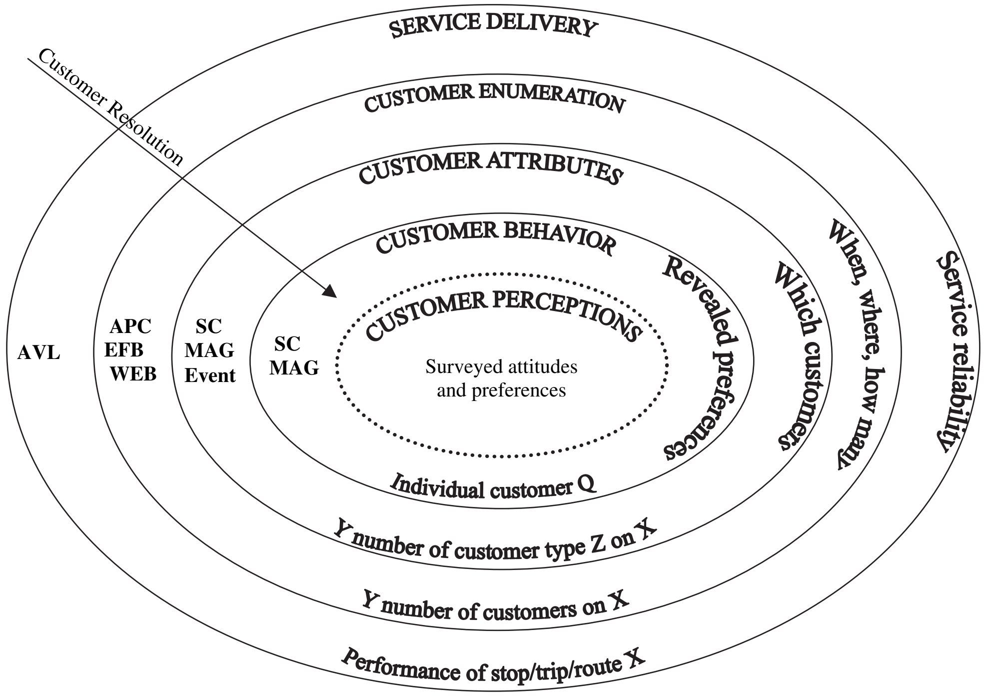

EFB: electronic registering farebox

Figure 2-5. ITS resolution in a market research context.

In the outermost ring of Figure 2-5, ITS technologies, such as AVL, provide information related to service delivery. At this level, customer identities and characteristics are completely unresolved within the data. One sees only the general service environment that a hypothetical customer would encounter. This level of resolution is suited to assessing research questions about the characteristics of service delivered to customers, such as on-time performance. Moving in to the second ring, technologies such as APC, magnetic stripe and smart cards, and Web and phone logs enumerate customers. At this level, anonymous customers can be located and counted, and these counts can address questions pertaining to when, where, and how many customers are using the system. Or, in the case of Web and phone logs, questions can be answered about how many customers are requesting information about particular services or are communicating information back to the agency.

Moving in to the third ring, technologies such as smart cards, magnetic stripe cards, and Mobile Data Recorders can relate data to specific customer groups. For example, a smart card or magnetic stripe card can be linked to a specific pass program participant, or records of lift deployments could link customers with disabilities to specific stops or trips. The data in this ring are useful for answering research questions about which customer groups are using a specific service or the system as a whole.

Finally, in the ring closest to the traditional market research core, technologies such as smart cards and magnetic stripe cards can potentially document the travel activity of an individual customer using the unique ID associated with each card. This ring represents the highest level of customer resolution obtainable with ITS technologies. Individual customers can be tracked through time and space within the system. For example, the transfer patterns of a specific customer could be tracked through the system as linked trips and compared over time. Deeper analysis of data at this level can even begin to reveal customer preferences. For example, given substitutable nearby transit services, the choice of one service over another may reveal a customer's valuation of selected service characteristics. Zhao (2004) uses analysis of this type to determine how CTA rail customers trade off travel time for comfort in the form of available seats and ease of transfers. Thus, ITS technologies collect transit data over a wide range of customer resolution levels, from general service delivery characteristics to individual customer actions and choices.

It is important to recognize the linked nature of ITS data. Because most transit ITS data are time and location stamped, data from different "rings" can often be joined. For this reason, it is better to think of the data layers moving toward the center as being complementary and cumulative. For instance, using the unique ID of an electronic fare card, a customer can be tracked through the system. These data exist within the customer behavior ring. Working toward the periphery, additional ITS data such as fellow rider attributes (customer attributes), passenger loads (customer enumeration), and schedule adherence (service delivery) could all be linked to

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the individual customer's travel, providing useful context data for analysis of travel choices. Relevant ITS data from any level can also be linked to the traditional market research core. For example, APC load data and AVL reliability data could be linked to surveyed customer perceptions of crowding and reliability, respectively, providing an opportunity for comparing perceived and actual conditions.

ITS data cannot be easily generalized. Different technologies record data at different levels of resolution. The resulting data have widely varying applications in market research. While ITS data cannot replace the core of traditional market research—individually stated preferences—in many cases, ITS technologies provide lower cost and expanded data that support and extend the core. The ability to use and link data from different resolution levels allows a more complete understanding of customer preferences and behavior. When combined, ITS and traditional data are highly complementary in addressing market research questions.

ITS technologies gather data on many aspects of service delivery and customer activity continuously, systemwide, and at low cost when compared to manual data collection. Traditionally, market researchers have relied on manual collection for such service delivery and consumption data. In an integrated market research system, different ITS data elements may replace, extend, or complement traditional market research data. However, certain information and data, especially those related to attitudes and non-rider characteristics, remain within the exclusive purview of traditional market research methods.

Figure 2-6 presents a graphical representation of the potential contribution of ITS data in six traditional market research applications: attitude studies, market segmentation analysis, customer satisfaction surveys, O-D studies, fare studies, and area analysis. Each research application's diagram in the figure provides a rough portrayal of how ITS data relate to traditional market research data sources, and also notes the primary data available relevant to the specific application.

First, the area uniquely within each rectangle in the figure represents the data requirements for each traditional market research application in the absence of ITS data. Next, the area uniquely within the ovals represents the range of data that ITS technologies make available. Finally, the area of overlap represents the opportunity for ITS data to combine with traditional market research data in each application. In this role, ITS data can facilitate or enrich traditional data collection and analysis. For instance, a customer satisfaction study on crowding could use APC-generated passenger load data to determine sampling times and locations. In addition, surveyed satisfaction data on crowding could be compared with actual passenger loads to relate perceptions of overcrowding to its actual incidence. Ideally, the APC data would be drawn from the actual trip where the survey was administered.

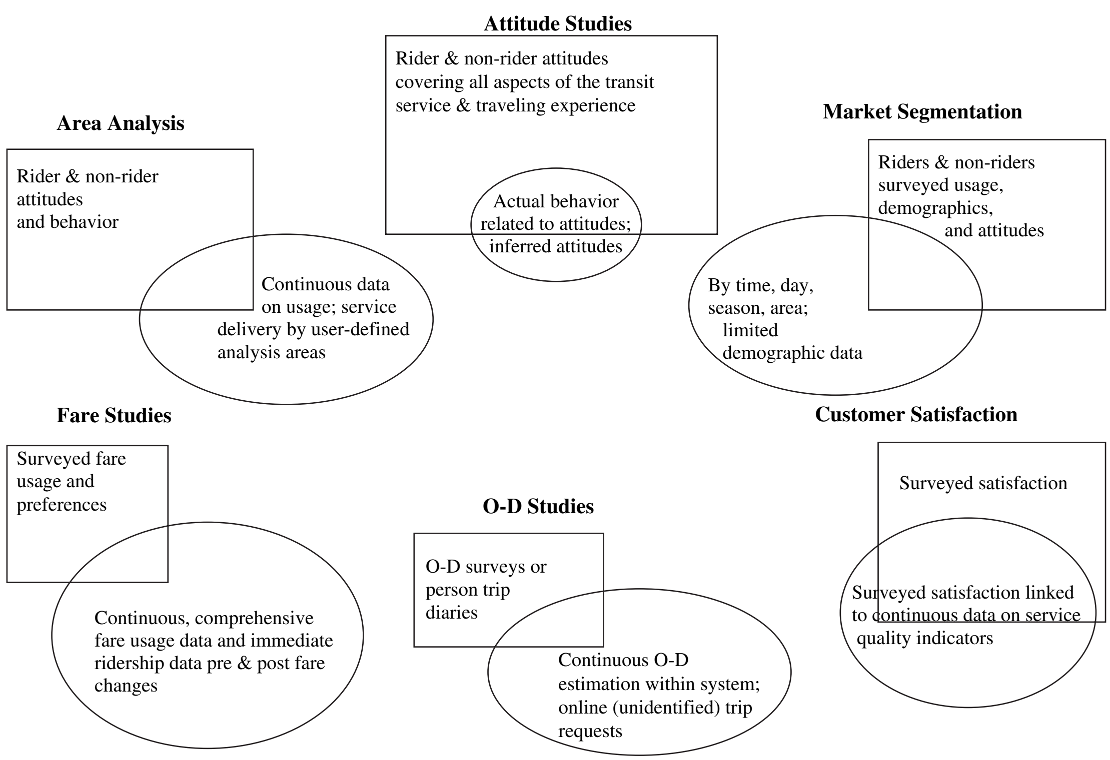

Figure 2-6. Traditional and ITS data in market research applications.

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Traditional market segmentation studies survey riders and non-riders to delineate distinct groups based on demographics, reported travel characteristics, and attitudes. ITS data collected from APCs and electronic fare cards can extend traditional data by providing continuous records on actual system use by time and location. For instance, using APC data, market researchers can segment different temporal user groups (e.g. time of day, day of week, or season) and analyze each group by location, ridership share, and trends over time. For example, using smart card data, Utsunomiya et al. (2006) segment CTA customers by residential location, transfer pattern, route/stop consistency of use, general frequency of use, and system access distance. Finally, ITS data can be combined with traditional data to enable or enrich market segmentation studies. A study seeking to segment off-peak riders, for instance, could use off-peak counts from APCs to target surveys or to provide sampling weights for expanding the survey results. APC data could also enrich traditional data by linking known market segments to actual system use. For example, areas with a preponderance of certain attitudinal groups (e.g., "transit lifestyle" or "necessity riders") could be linked with the areas' actual ridership data and further analyzed along temporal dimensions (e.g., weekday/weekend, peak/off-peak, seasonal).

Customer satisfaction is usually gauged by surveys. ITS technologies allow stated satisfaction and customer feedback to be linked with actual service delivery data. For example, TriMet (Appendix C) has compared surveyed perceptions of "overcrowding" with actual passenger loads on specific trips recorded by APCs. The comparison provides a more nuanced understanding of how actual conditions relate to customer perceptions and satisfaction. In addition, important factors influencing customer satisfaction that emerge from satisfaction surveys may be monitored continuously to better understand trends between surveys. This monitoring function may permit earlier market research findings to be used preemptively to forestall decreases in customer satisfaction. For example, periodic satisfaction surveys at TriMet (Appendix C) revealed that both reliability and overcrowding were increasingly affecting overall rider satisfaction. Analysis of AVL and APC data suggested that deteriorating headway maintenance (i.e., bus bunching) was related to the downward satisfaction trend. Thus, the combination of traditional and ITS data within market research can provide managers with both satisfaction metrics and related service delivery measures to address conditions related to customers' concerns. In this example, operations managers at TriMet became aware of the importance of maintaining headways in order to improve customer satisfaction rather than simply promoting headway adherence as "good operations practice."

O-D studies are conducted by surveying riders or a sample of households and extrapolating the data to construct trip tables. ITS data can both support traditional survey techniques and provide independent O-D estimates, with or without survey-based validation. Survey-based O-D trip tables can be checked for correspondence with APC or smart card data. APC boarding/alighting totals by stop can be compared with survey-based estimates, or individual household travel surveys can be compared with actual transit trips recorded by household smart cards over the survey period. CTA plans to use both of these approaches in future O-D survey efforts (see Appendix A). Furthermore, ITS technologies can provide either direct O-D data or inputs suitable for O-D estimation. Rahbee and Czerwinski (2002) report accurate O-D estimates for rail passengers using fare card data on boardings only. As electronic fare card use becomes more widespread, ITS data also promise low-cost updating of trip tables between the times when traditional surveys are undertaken.

Fare studies are traditionally undertaken using a combination of surveyed fare preferences and manually collected fare usage data. ITS data from electronic fare cards and electronic fareboxes can largely replace manually collected usage data and provide continuous, accurate fare usage data. For example, City of Madison Metro Transit (Appendix B) has used magnetic stripe card data on pass program users in negotiating pass program contracts with employers and institutions in their district. ITS data can also support ongoing monitoring of customer responses to fare changes and validation of survey-based fare models. The CTA (Appendix A) analyzed actual fare card usage data in updating its survey-based fare change model. APC data might be used to monitor ridership changes following a fare change. ITS data on fare use can also combine with traditional surveys to better understand changes among different market segments. CTA compared demographics and perceptions of smart card users with those of other riders and non-riders to better understand why certain customer groups prefer specific fare options. Thus, ITS data on fare choice and response to fare changes improves the currency of fare data and extends analysis possibilities.

Area analysis is often performed by surveying riders and non-riders in a defined geographic area, and recovering their attitudes and preferences regarding existing or planned transit service. Because most ITS data are location stamped, organizing them around specific analysis areas is relatively easy. Furthermore, the ability to define the analysis area after data are collected provides a considerable advantage over traditional surveys. ITS data provide continuously updated information on both service delivery and usage within any defined analysis area. For example, Utsunomiya et al. (2006) examine consistency of station and route choices in different areas using smart card data, finding that some areas' usage patterns vary considerably more than others. Such analysis provides the market researcher with a better understanding of the customer types served in specific areas. There is also potential for leveraging ITS data for specific areas with survey-based area analysis. Perceptions about service quality could be compared with actual area service performance to determine whether, for instance, an area with below average perceptions of reliability actually experiences lower than average reliability, as measured by AVL.

Attitude studies constitute much of the core activities of traditional market research practice and are typically administered by intercept, phone, or mail methods. While ITS technologies cannot recover customer attitudes directly, there are opportunities for ITS data to support and extend traditional attitude studies. In the simplest case, ITS data on stop-level ridership can be useful for planning and expanding user attitude surveys. Surveyed attitudes and attitude trends can also be compared with corresponding service delivery trends to discern whether customers are becoming more or less sensitive to specific service quality conditions or whether the service conditions themselves are changing. In addition, in certain cases ITS data provide a sufficient basis to directly infer customer preferences. For example, Zhao (2004) estimates the implied monetary value of service amenities like seat availability and ease of transfer using smart card data on passengers' choices among substitute rail services. Thus, while traditional techniques remain the primary tool for gathering rider and non-rider attitudes, ITS data can in many cases facilitate data collection or enrich the interpretation of results.

It should be mentioned that Figure 2-6 simplifies potential research applications somewhat. In fact, data typically associated with one application may be useful for answering questions in other applications as well. This is especially true with combined traditional and ITS data. For instance, the CTA has considered combining fare card data on college student pass riders (fare study) with surveyed perceptions of safety (customer satisfaction) to assess whether the presence of college students on certain routes improves riders' perceptions of safety. Thus, the diagram probably understates the total contribution of ITS data to each market research application.

ITS data provide useful inputs for various market research applications. In many cases, ITS technologies provide data that are useful for addressing market research questions directly. Some of the data are entirely new and some replace traditional data gathering techniques at lower cost and with improved currency. In other cases, ITS data enable or enrich traditional data gathering and analysis. Finally, some data remain within the exclusive purview of traditional market research methods. The size and scope of the contribution of ITS data to market research vary by application and by the data analysis capabilities of a transit agency's market research staff.

CHAPTER 3

ITS Data Applications in Market Research

To this point, transit market research methods and activities have been described, and the data recovered by ITS technologies have been inventoried. In this chapter, market research and ITS data are combined to illustrate the role that the data can play in complementing, extending, and leveraging market research practices. The following presentation reflects the position of market research within the integrated marketing system, as was shown in Figure 1-1.

In an integrated marketing system, ITS data applications support a market research program in two distinct ways. First, ITS data can be employed in monitoring and evaluating program outcomes in a process where market research contributes to the definition of marketing action plans, and these plans, in turn, are implemented in the service delivery, promotional, and customer service functions of a transit agency. The knowledge gained through monitoring and evaluation then allows an integrated marketing system to be realized as a dynamic process by informing subsequent market research activities. Examples if ITS data applications in monitoring and evaluating the delivery of services to customers are presented in the next section.

The second way that ITS data support the market research function is more direct. Here, ITS data can be applied to facilitate the execution of traditional market research methods. The data can also be used to either maintain the currency of market research products or to provide a surrogate reference against which other market research products can be evaluated. In these capacities, applications of ITS data serve to leverage the market research process. Examples of such applications are presented in the final section of the chapter.

The examples of ITS data applications in support of market research are drawn from the transit literature and from case studies of three transit properties. The literature offers a number of examples of how ITS data can be used to monitor service delivery. This is not surprising given that service delivery monitoring was an important reason for acquiring several of the systems under study. In contrast, examples of using ITS data to leverage market research are drawn mainly from the case studies, suggesting that these applications are still emerging and have not yet reached the mainstream of practice within the transit industry.

The selection of case study properties occurred through several steps. First, an online survey of properties that had deployed or planned to deploy the technologies of interest—identified from the Volpe Center deployment surveys—was administered in July and August 2005. A total of 134 properties were solicited to participate in the survey and 78 ultimately responded. The survey recovered information on the scale and scope of properties' market research activities, the deployment status of the subject technologies, the ITS data archiving environment, applications and tools used in ITS data analysis and reporting, issues related to experiences in accessing and using ITS data, and lessons learned from those experiences.

Evaluation of the survey responses led to the identification of 13 candidate case study properties. Telephone interviews were conducted with each property in April 2006. The final selection of properties—the CTA, TriMet, and City of Madison Metro Transit—reflected an interest in recovering information that collectively represented all fixed route modes, the technologies of interest, varying levels of experience with ITS data applications in market research, and a range of property sizes.

ITS Data Applications: Monitoring Service Delivery

Figure 3-1 presents an inventory of questions related to service delivery that can be addressed using ITS data. The questions are organized around the six subject areas commonly covered in market research programs (as previously illustrated in Figures 1-1 and 2-6): area analysis, attitude studies, customer satisfaction, fare studies, market segmentation, and O-D studies. Although it is not directly within the realm of market research, a seventh subject area covering customer service and customer information is also included in Figure 3-1.

Research Area	ITS Technology*	ITS Data	Application	Reference
Area Analysis	***What is the quality of service delivered to customers in defined service areas?***			
	APC (+GIS)	*Load Summaries by Defined Area*	Analyze loads/overloads for a defined area (segment, route, corridor, system) for a defined time period	TriMet Case Study
	AVL	*Depart Times, Arrive Times*	Calculate run times and run time variation for segments and routes by service period	TriMet Case Study CTA Case Study Levinson (1991)
	AVL	*Depart Times, Arrive Times*	Calculate schedule adherence and headway maintenance by defined area	TriMet Case Study
	MDT	Event Counts	Compile security, mechanical, or accident events by defined analysis area	FTA (2005)
	Where do customers access and use the system?			
	APC, MAG, SC	*Boarding & Alighting Summaries by Stop or Station*	Create a "passenger census" using station or stop-level boardings and alightings for a defined time period	TriMet Case Study CTA Case Study
	APC (+GIS)	*Boarding & Alighting Summaries by Stop*	Display passenger counts by defined area (e.g., CBD)	FTA (2005)
	SC (+GIS)	Card ID, Date & Time, Vehicle ID	Analyze smart card transactions by defined analysis area for a defined time period	Lehtonen et al. (2002) CTA Case Study
	When do customers use the system?			
	APC	*Boarding & Alighting Summaries by Time of Day, Day of Week or Season*	Analyze boardings by time of day (peak/off-peak), day of week (week/weekend), and season by defined analysis area	--
	Which customer groups access the system in defined service areas?			
	SC (+GIS)	Card ID, Date & Time, Transaction ID (+geocoded registered address)	Calculate frequency of use by residence location (inferred from billing address)	Utsunomiya et al. (2006)
	How do different customer groups access and use the system?			
	SC (+GIS)	Card ID, Date & Time, Vehicle/Station ID, boarding location (+geocoded registered address)	Graphically analyze mode choices within a defined analysis area	CTA Case Study
	MAG or SC (+GIS)	Card ID, Date & Time, Vehicle/Station ID, boarding location (+geocode analysis zones)	Analyze day-to-day consistency of system access point and/or route path by defined analysis area	Utsunomiya et al. (2006)
	How is transit use changing or likely to change over time in specific service areas?			
	APC (+GIS)	*Boarding & Alighting Summaries by Stop*	Compare current and past ridership by defined analysis area	FTA (2005)
	APC (+GIS)	*Boarding Summaries by Stop*	Estimate stop-level boardings using combined APC stop and area tax-lot data for defined time periods	Kimpel et al. (2007)
	How are customers responding to new service, changes in service, service delivery, or marketing?			
	APC, AVL	*Boarding & Alighting Summaries by Stop, Route; Running Time Summaries by Route; Actual v. Scheduled Leave Times by Time Point*	Monitor ridership, on-time performance, and schedule efficiency for service extended to new markets.	Gehrs et al. (2007)
	APC	*Boarding & Alighting Summaries by Stop, Route*	Monitor ridership on affected service before and after service changes	FTA (2005); TriMet Case Study
	AVL (+APC)	*Performance Summaries by Trip, Route* (*+Boarding Summaries by Trip, Route*)	Monitor ridership before and after measured performance changes	FTA (2005)
	MDT	Date & Time, Operator-keyed bicycle loading event	Evaluate ridership changes during promotional period (e.g., bicycle on bus customers ride free)	Schneider (2005)
	SC	Card ID, Date & Time, Vehicle/Station ID	Monitor individual customer behavior on targeted service before and after changes	CTA Case Study
	How many customers and travelers are shelter or on-board advertisements likely to reach?			
	APC, Traffic Counters	*Boarding Summaries by Stop, Route*	Use boarding totals to estimate number of on-board ad views (use boarding & alighting totals with traffic counts for shelter ads)	Madison Case Study
Attitude Studies	***How do customers make trade offs among different service variables?***			
	APC (+GIS)	*Boarding Summaries by Stop*	Estimate the effects of access distance on stop-level ridership	Kimpel et al. (2007)
	MAG or SC	Card ID, Station ID, Alighting Location (recorded or imputed)	Estimate implicit monetary value of comfort and convenience by analyzing customer trade offs between travel time and other trip characteristics (e.g., seat availability, transfer impediments) when substitute service is available	Zhao (2004)

Figure 3-1. Applications of ITS data: monitoring service delivery.

(continued on next page)

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Research Area	ITS Technology*	ITS Data	Application	Reference
	SC (+GIS)	Card ID,Station ID, Alighting Location (recorded or imputed)	Analyze trade offs across different customer groups (either collected directly or inferred from census data based on billing address) between travel time and comfort when substitute service is available. When both bus and rail service is available, which is chosen? Is one chosen over another despite a longer access or travel time?	CTA Case Study
Customer Satisfaction	***How crowded is the service?***			
	APC	*Load Summaries by Route, Stop*	Analyze loads/overloads by stop, trip, route, or service type	FTA (2005)
	APC	*Load Summaries by Trip Segment and Peak Hour*	Calculate volume/capacity ratios for service over defined times and corridors	TriMet Case Study
	How reliable is the service?			
	APC, AVL	Stop-Level Boardings, Headways	Calculate excess wait times based on headway adherence and boardings	TriMet Case Study
	AVL	Date & Time, Vehicle ID	Compare customer reliability complaints with actual performance	Madison Case Study
	AVL	*Arrive Times, Depart Times*	Compare schedule adherence and headway maintenance by trip or route	FTA (2005)
	MAG or SC; AVL, APC	Card ID, Date & Time; Boardings; Arrive Times; Depart Times	Calculate percentage of customers experiencing "acceptable" wait times	CTA Case Study
	How safe is the service?			
	MDT	Event Counts	Compare security, mechanical, accident, or shelter vandalism events by stop, trip, route, service type, or area	FTA (2005)
	How will print information best reach customers?			
	APC	*Boarding & Alighting Summaries*	Target stops for information displays	CTA Case Study
	GIS	Census Block Group Data	Identify languages spoken at home (inferred from census data) near identified stops & stations to provide customer information in appropriate languages	CTA Case Study
	SC (+GIS)	Card ID, Boarding History (+ geocoded registered address)	Identify customers likely to be affected by service interruptions/changes	CTA Case Study
	Where should stop facilities be upgraded or deployed?			
	APC	*Boarding & Alighting Summaries by Stop*	Use stop-level boardings & alightings to prioritize facility improvements based on passenger volumes	TriMet Case Study; Madison Case Study
	APC (+GIS)	*Boarding & Alighting Summaries by Stop*	Present stop-level activity on a map to communicate stop relocation rationale to public	Madison Case Study
	AVM	*Lift Event Summaries*	Use stop-level lift deployments to prioritize facility improvements for customers with disabilities	TriMet Case Study
Fares	***What is the frequency of use of different fare types?***			
	MAG or SC	Card ID	Analyze ridership for specific pass program clients	Madison Case Study
	EFB, MAG, SC	*Farebox & Card Transaction Summaries*	Calculate shares of smart card, magstripe, & cash transactions	Utsunomiya et al. (2006)
	SC	Card ID, Date & Time	Calculate turnover rate among smart card users (i.e., what portion of smart cards become inactive over a given period). On systems with high rates of smart card use, this may proxy ridership turnover rates.	Bagchi and White (2005)
	How do customers respond to fare changes?			
	APC	*Boarding Summaries by Stop, Trip, Route*	Compare ridership on affected service before and after changes	FTA (2005) TriMet Case Study
	SC	Card ID, Date & Time, Vehicle/Station ID	Compare individual customer behavior on affected service before and after changes	CTA Case Study
	Which customers prefer smart cards?			
	SC (+GIS)	Card Registration Address, Census Block Group Data	Compare smart card users as a group by customer demographics (either collected from cardholders or inferred from census data based on registration)	CTA Case Study
	How much fare revenue are we collecting per route?			
	EFB, MAG, SC	*Transaction Summaries*	Calculate fare revenue by route	CTA Case Study
	How do customers use stored value cards?			
	MAG or SC	Card ID, transaction records	Analyze frequency and amount of typical card recharges	CTA Case Study

Figure 3-1. (Continued).

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Research Area	ITS Technology*	ITS Data	Application	Reference
Market Segmentation & Marketing	***When do customers use the system?***			
	APC	*Boarding Summaries by Time of Day, Day of Week or Season*	Analyze boardings by time of day (peak/off-peak), day of week (week/weekend), and season by stop, trip, route, or service type	TriMet Case Study
	AVM	Date & Time, Lift Event	Analyze lift use by time of day or day of week	FTA (2005)
	MDT	Date & Time, Operator-keyed bicycle loading event	Analyze bicycles on bus trips by time of day, day of week, or season	Schneider (2005)
	SC	Card ID , Date & Time	Analyze temporal dimensions of smart card use	Lehtonen et al. (2002)
	SC (+GIS)	Card ID, Date & Time (+geocoded registered address)	Compare day of week, time of day, or seasonal usage by customer demographics (either collected from cardholders or inferred from census data based on billing address)	CTA Case Study
	Where do customers access and use the system?			
	APC	*Boarding Summaries by Stop, Route*	Analyze aggregate use by stop or route	TriMet Case Study
	MDT	Date & Time, Operator-keyed bicycle loading event, Vehicle ID	Analyze bicycle loadings on bus trips by boarding location	Schneider (2005)
	MDT, AVM	Event Records	Analyze boarding locations of special customer groups (disabled customers, fare evaders, young riders)	TriMet Case Study
	MAG	Card ID, Transaction ID	Combine census data with fare card data to develop route user profiles	Madison Case Study (planned)
	SC (+GIS)	Card ID, Vehicle/Station ID (+geocoded registered address), Census Block Group Data	Analyze stop or station use by customer demographics	CTA Case Study
	How do different customer groups access and use the system?			
	MAG or SC	Card ID, Date & Time, Vehicle/Station ID	Segment individual customers by travel patterns over day, week, month, year	CTA Case Study
	MAG or SC	Card ID, Date & Time, Vehicle/Station ID	Segment customers by consistency of access point, route, or service type	CTA Case Study
	MAG or SC	Card ID, Date & Time, Vehicle/Station ID	Segment customers by modal transfer pattern (e.g., rail-bus-rail) and analyze frequency of each pattern	Utsunomiya et al. (2006)
	SC	Card ID, Date & Time	Segment individual customers by frequency of use	--
	SC	Card ID, Vehicle/Station ID	Compare customer demographics by service type (e.g., bus/train, local/express)	--
	SC	Card ID, Vehicle/Station ID, Time	Compare transfer patterns by customer demographics	--
	SC	Card ID	Analyze ridership patterns of specific pass program groups (e.g. elderly, students, employees) over time	Bagchi and White (2005)
	SC (+GIS)	Card ID, Date & Time, Vehicle/Station ID, Date and Time (+geocoded customer address, geocoded transit stops)	Segment customers by system access distance over actual travel network	Utsunomiya et al. (2006)
	How are the shares of different segments changing over time?			
	APC	*Boarding Summaries by Time of Day, Day of Week or Season*	Compare current and past ridership by time of day (peak/off-peak), day of week (week/weekend), and season by stop, trip, route, or service type	TriMet Case Study
	EFB, MAG, SC	Card ID	Analyze changes in shares of different fare media or pass programs	CTA Case Study
	SC	Card ID	Analyze changes in frequency of use by customer demographics	--
	What is the ridership to special events?			
	APC or EFB	*Boarding Summaries* or Farebox Transaction Data for Trips Serving Event	Analyze ridership to special events	CTA Case Study
	MAG or SC	Card ID, Date & Time, Vehicle/Station ID	Analyze individual linked trips to special events	CTA Case Study
	SC	Card ID, Date & Time, Vehicle/Station ID, Customer Information	Analyze demographic information (either collected from cardholders or inferred from census data based on billing address) for special event customers	--

Figure 3-1. (Continued).

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Research Area	ITS Technology*	ITS Data	Application	Reference
Origin-Destination	***Which system origin-destination pairs are accessed by customers?***			
	EFB	Boardings	Estimate origin-destination patterns	Navick and Furth (2002); Barry et al. (2002); Richardson (2000)
	SC, MAG	Card ID, Vehicle/Station ID, Boarding Location	Analyze inferred or actual destinations by customer information for rail trips	Rahbee & Czerwinski (2002); CTA Case Study
Customer Service Information & Human Resources	***What origin-destination pairs are customers requesting trip planning information about?***			
	Phone/Web Trip Planning Logs	Requested Origins and Destinations; Path Chosen	Analyze requested origins and destinations of phone and website users by desired departure time	Trepanier et al. (2005)
	What are the travel preferences of customers requesting trip planning information?			
	Phone/Web Trip Planning Logs	Requested Origins and Destinations; Requested Travel Options	Analyze trade offs by Web users between travel time and other trip characteristics (e.g., walk distance, transfers)	Trepanier et al. (2005)
	What stops are queried for real time arrival information?			
	Phone/Web Arrive Time Logs, APC	Stop ID, Date, Time, Boardings & Alightings	Analyze the pattern of requests for arrival times in relation to actual stop-level boardings and alightings to assess real time information needs	--
	Are customers well informed about service changes and special circumstances?			
	Phone/Web Logs, APC	Page Views, Call Bin Code Counts, Boardings & Alightings	Analyze the share of affected customers requesting information about construction, re-routes, schedule, fare, & service changes, and inclement weather service. If the share is low, consider redesign of phone/Web information or supplement with information dissemination through other media	TriMet Case Study CTA Case Study
	How can customer complaints about service delivery be assessed?			
	Phone/Web Logs, AVL, MDT	Route/Trip/Operator ID, Depart Times, Speed, Event Code	Check "leave early" complaints against actual depart times; check passup complaints against overload events; check speeding complaints against actual speeds	Madison Case Study [TriMet Case Study]
	Are commendations or complaints and service delivery performance related?			
	Phone/Web Logs, AVL, APC, MDT	Route/Trip/Operator ID, Arrive & Depart Times, Passenger Loads, Event Counts	Analyze the relationship between complaint or commendation counts and on-time performance, passenger loads, and relevant event counts from the operator-trip level to the route-time period level	Strathman et. al (2002)

Note: Italicized entries in the ITS data column indicate a need for the ITS data to be processed or analyzed to address a given market research question.

APC = Automatic Passenger Counters
AVL = Automatic vehicle location
AVM = Automatic vehicle monitoring
EFB = Electronic registering farebox
GIS = Geographic information system
MAG = Magnetic stripe card
MDT = Mobile data terminal
SC = Smart card

Figure 3-1. (Continued).

Within each subject area, a series of service delivery-related questions is listed. Following each question, the ITS technologies and relevant data elements supporting analysis are identified. A brief description of the analysis is then given, along with a reference to the literature or a case study where further elaboration can be found.

As Figure 3-1 reveals, ITS data are more capable of analyzing service delivery questions in some subject areas than in others. For instance, ITS technologies are very useful in providing continuous data on service performance and utilization in specific analysis areas, while automated data collection is less useful in service delivery analysis corresponding to attitude studies. Similarly, the technologies themselves are more effective addressing questions in some areas than in others. For example, the continuous reliability data collected by AVL is essential in analyzing many service delivery questions that relate to customer satisfaction, while it has limited usefulness in addressing fare-related questions. In general, ITS data are most useful for answering questions about *when*, *where*, *how*, and *how many* regarding service delivery or customer activity. Electronic fare cards with unique IDs can also answer some questions about *which* customers are making specific trips. Generally, ITS data are less capable of addressing service delivery questions about *who* customers are and *why* they are behaving as they do.

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In some applications, data from more than one ITS technology can be used to address a service delivery question, although different levels of customer or system resolution may call for different data or analysis techniques. For example, the market segmentation question "What is the ridership to special events?" can be addressed using APC, EFB, magnetic stripe, or smart card data, but the details captured will differ by technology. For this particular question, APCs provide only passenger counts; EFBs further segment boardings by fare type; magnetic stripe or unregistered smart cards provide additional detail on linked trip paths; and registered smart cards provide customers' identities and place of residence. All of the listed technologies provide data suitable for addressing the general research question; however, the depth of analysis is limited by the level of customer resolution that each ITS technology is capable of achieving. Thus, even if an agency currently has only a partial complement of the technologies just listed, the data still may be suitable for analyzing a considerable range of market research questions.

Particularly when the object of analysis is a specific area or set of areas, integration of ITS data with a GIS is a convenient way to incorporate spatial boundaries. Because ITS data are usually available for an entire transit system, the potential for spatial analysis of user-defined subareas is great. Unlike a traditional survey in which geographic sampling boundaries must be set in advance, analysis area boundaries can be drawn and redrawn as necessary with locationally referenced ITS data. GIS applications using ITS data also allow the incorporation of census demographic data or tax-lot data for a defined service area. Finally, the mapping capability of a GIS provides an effective means of communicating analysis and information to decisionmakers and stakeholders.

ITS Data Applications: Leveraging Traditional Market Research

In addition to applications of ITS data in monitoring service delivery, the case studies identified examples in which ITS data are combined with traditional methods and data. Figure 3-2 presents a range of applications in which ITS data combines with traditional market research methods and data. The applications are organized by traditional market research data collection methods: on-board surveys, telephone surveys, on-street surveys, mail surveys, and focus groups. Following the organization of applications in monitoring service delivery, the presentation in Figure 3-2 identifies the specific technologies and data elements or reports necessary to perform the analysis, and refers to the case study where such analysis has been performed.

On-board surveys benefit from ITS data in the research design, survey administration, and response evaluation phases. By providing documentation of actual customer flows through the system, APC and/or fare card data prevent researchers from entering the field "blind," or with incomplete or outdated information. For example, passenger counts by time and location provide a contemporary census of the riding population, from which sampling plans can be designed and personnel and other resources can be assigned (TriMet Case Study). After survey data are collected, ITS data on actual service attributes can be compared with surveyed perceptions and attitudes to obtain a more complete picture of customer preferences (CTA Case Study; TriMet Case Study). Finally, completed surveys may provide inputs into subsequent ITS data analysis by validating, for example, O-D models estimated from fare transactions data (CTA Case Study). ITS data can thus enter at any point in the cycle of an on-board survey project: from design through administration, analysis, and evaluation.

Telephone surveys are commonly used to gather attitudinal data from both riders and non-riders. Surveyed perceptions of specific service attributes can be compared with actual system performance, as measured by ITS data. Joint analysis of survey responses and service delivery data can then be used to target service improvements with the greatest potential for improving satisfaction and increasing ridership (TriMet Case Study).

Although they do not constitute a scientific sample, customer complaints provide important snapshots of customer perceptions of service quality. TriMet and Madison Metro compare customer complaints with ITS data to "validate" the complaint (e.g., was a given bus actually speeding, or did it actually leave the stop early?), to explain to a customer why the event associated with their complaint occurred (e.g., does event data indicate that a pass-up occurred because the vehicle was overloaded or directed by dispatch to skip stops?), or to better understand how actual operating conditions relate to rider perceptions (e.g., are routes with more complaints per thousand boardings also less reliable or subject to more crowding?).

On-street intercept surveys benefit from ITS data in many of the same ways as on-board surveys. Data on passenger movements from APCs and electronic fare cards aid in identifying intercept locations (TriMet Case Study). Other ITS data contribute to the analysis of intercept data. ITS data on reliability and passenger volumes can be used to identify similar locations to use as a "control" when surveying a "treatment" group's perceptions of service improvements (CTA Case Study). Intercept surveys can also inform or validate models estimated from ITS data. For instance, CTA intends to use intercept surveys to validate its electronic fare card-based O-D model. By providing service delivery data covering an entire transit system, ITS data provide useful inputs for intercept surveys; at the same time, intercept surveys also provide key data inputs to support models estimated from ITS data.

Research Method	ITS Technology*	ITS Data	Application	Reference
On-board Surveys	APC	*Load Summaries by Stop, Route*	From load summaries, determine sampling rates, how many surveys to print, and weighting factors for expanding sample survey responses to population totals	[TriMet Case Study]
	APC	*Load Summaries by Route, Trip*	Survey responses on satisfaction with "overcrowding" are compared with passenger load data to identify specific circumstances where high passenger loads are affecting customer satisfaction	[TriMet Case Study]
	APC	*Load Summaries by Route, Trip, Stop*	Survey vendors draw on stop and route passenger data to gain a better understand of the dynamics of the system's operating environment	[TriMet Case Study]
	APC	*Load summaries by Stop*	Compare downtown trip estimates from O-D survey with the number of APC boardings/alightings downtown	[TriMet Case Study]
	AVL	*Performance Reports by Route*	Compare route-level reliability indicators (on-time performance, headway maintenance, excess waiting time) with surveyed satisfaction with "reliability" to assess correspondence	[TriMet Case Study]
	APC, MAG, SC	*Boarding and Fare Card Use Summaries by Trip, Stop*	Inform sampling plan and provide expansion factors for O-D survey	[CTA Case Study]
	MAG, SC	*Transaction Summaries*	Calibrate stated preference-based Fare Change Model using actual card usage data	[CTA Case Study]
	GPS/GIS	Geocoded Survey Locations	Use geocoding digital pens to record where surveys were administered	[CTA Case Study]
	MAG, SC	*Transaction Summaries by Pass Group*	University student (Upass Card) ridership related to surveyed perceptions of safety and security	[CTA Case Study (considering)]
	SC, MAG	Card ID, Date & Time, Vehicle/Station ID	Use fare card data to continuously update survey-based O-D tables (after initial validation using on-board O-D survey totals)	[CTA Case Study]
Telephone Surveys	APC, AVL	*Load Summaries, Performance Reports*	Compare surveyed customer satisfaction on specific service attributes with actual system performance on specific attributes to identify improvement areas with greatest potential to improve satisfaction	[TriMet Case Study]
	APC, AVL	*Load Summaries, Performance Reports*	Compare changes in customer perceptions of service attributes over time with actual performance trends to determine whether actual performance trends correspond to changes in customer satisfaction	[TriMet Case Study]
	APC, AVL (+GIS)	*Load Summaries by Route, Trip, Stop; Service Frequency & Coverage*	Given attitudinal market segments determined by surveys, evaluate effectiveness of targeted marketing/service improvement programs by comparing ridership response in areas where targeted segments are prevalent versus other areas	[TriMet Case Study]
	MAG	*Card Usage Summaries by Stop, Route*	Employ card usage data to inform sampling plan for perceptions survey	[Madison Case Study (planned)]
	SC	Card ID	Compare surveyed demographics and perceptions of registered and non-registered smart card users with those of other riders/non-riders	[CTA Case Study]
On-street Surveys	APC	*Boarding & Alighting Summaries by Stop*	Identify stops with similar passenger volumes to use as treatment and control groups for survey of perceived reliability before and after installation of real time arrival displays	[CTA Case Study]
	AVL	*Performance Reports on Stop-level Reliability Indicators*	Compare surveyed customer perceptions of waiting time and reliability with changes in actual reliability indicators before and after a change (e.g., installation of real time arrival display)	[CTA Case Study] Schweiger (2003)
	APC	*Boarding & Alighting Summaries by Stop by Period*	Determine the best times to survey and when or where more than one surveyor is needed	[TriMet Case Study]
	MAG, SC	Card ID, Date & Time, Station ID	Use surveys to validate cross-platform transfer rates estimated from card data	[CTA Case Study]
Mail Surveys	APC	*Load Summaries by Route, Trip, Stop*	Use ridership data for household travel survey sampling and expansion factors	[TriMet Case Study (planned)]

Figure 3-2. Applications of ITS data: leveraging traditional market research methods.

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Research Method	ITS Technology*	ITS Data	Application	Reference
	MAG	*Card Transaction Summaries by Pass Group*	Replace pass program user surveys with card transaction summaries to document pass program ridership in negotiating pass program contracts	[Madison Case Study]
	SC	Card ID, Transaction Date & Time, Vehicle/Station ID	Validate household travel survey responses with actual recorded transit trips from smart cards issued to survey respondents	[CTA Case Study (planned)]
Focus Groups	MAG, SC	Card ID and Card Usage History; Customer Contact Information	Structure fare policy focus groups by card type and use to represent different perspectives	[CTA Case Study]
	APC, AVL	*Load Summaries and Performance Reports*	Recruit "rider experience" focus group based on actual service delivery data	[TriMet Case Study]

Note: Italicized entries in the ITS data column indicate a need for the ITS data to be processed or analyzed to address a given market research question.

APC = Automatic passenger counter
AVL = Automatic vehicle location
GIS = Geographic information system
GPS = Global positioning system
MAG = Magnetic stripe card
SC = Smart card

Figure 3-2. (Continued).

The three case study properties had not yet directly combined ITS data with mail surveys. However, both CTA and TriMet plan to incorporate ITS data in the future. ITS data could potentially provide sampling and expansion factors for travel diary surveys. In addition, if survey participants are given registered smart cards, trips recorded by the cards could serve as a check on transit trips recorded in travel diaries. The correspondence between participants' "smart card trips" and "diary trips" could be assessed to determine underreporting rates and provide prompting information to correct diaries for missing or misreported trips.

For transit properties with websites, web logs of site visits can provide information on how well information is reaching customers. TriMet tracks how many times important service announcements are viewed. If views are less frequent than expected, additional communication may be needed.

ITS data is useful for focus group research, particularly for selecting participants. Both CTA and TriMet have used fare card and APC data to target specific rider groups in efforts to capture a desired range of customer perspectives. For example, fare policy focus groups may be structured by fare card type and use data.

As in the case of service monitoring applications presented in Figure 3-1, the leveraged applications presented in Figure 3-2 do not exhaust the potential of ITS data to support transit market research. As ITS data become more familiar and accessible to market researchers, additional applications will be developed. Even so, the applications reported by the case study properties provide a framework for pursuing leveraging opportunities. First, ITS data provide inputs about system activity that facilitate the use of traditional market research methods. Second, since ITS technologies gather data continuously and comprehensively, they allow surveyed perceptions and preferences to be compared with actual service performance. Third, leveraging may also work in the reverse direction, with traditional survey techniques providing benchmark information for validating models based on ITS data.

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CHAPTER 4

Data Management, Reporting, and Staffing Considerations

Effective use of ITS data to support and leverage transit market research depends on the development and maintenance of a diverse supporting infrastructure. Key elements of this infrastructure include an information system for archiving ITS data; enterprise-level applications, the most important of which in the context of this Guidebook is GIS; processes for screening and validating ITS data to ensure its integrity; software tools that support reporting and analysis; and human resources with the skills to maintain the infrastructure and, through analysis of ITS data, inform strategic decisions in marketing and other agency functions. This chapter addresses these infrastructure elements, which collectively separate ITS technologies from decisionmaking. When this infrastructure is properly developed and supported, the potential of ITS data to support research, inform decisions, and benefit customers can be realized. When the infrastructure includes gaps, inconsistencies, or incompatibilities, the potential benefits can be entirely lost.

The presentation in this chapter draws on information recovered in the 2005 survey of properties that had deployed or were planning to deploy the technologies covered in this Guidebook. It also draws on the experiences of the three case study properties, which collectively have succeeded in bridging the technology-decisionmaking gap. Finally, the chapter draws on the literature related to each of the infrastructure elements.

Enterprise Database Architecture Supporting the Use of ITS Data

ITS technologies have the potential to provide substantial information to support and leverage transit market research. Among the transit agencies surveyed in 2005, the potential to provide information for market research was often reported to be blunted by problems with managing ITS data in a manner that allows marketing and others within the organization to readily use the data. Many of the properties surveyed did not have the capability to validate, organize, retrieve, share, and analyze the ITS data collected. Marketing was found to often rely on the "trickle down" of information collected by others. Thus, the frequently compromised capability to manage ITS data across the organization represents a crucial roadblock for market researchers seeking access to data. This section is intended to provide an overview and direction with respect to developing the enterprise or organizationwide tools and architecture for managing ITS data.

Current Data Practices

At many of the properties surveyed, the collection of ITS data is done on a departmental or project specific basis. This information is used for specific applications and is not stored in a manner that allows others, such as marketing, to easily retrieve or share the information. While information can theoretically be shared, it usually requires technical expertise and a level of effort that marketing typically does not have. There are a number of factors contributing to this problem, including the following:

- Lack of budget
- Lack of information technology (IT) tools, such as databases
- Problems integrating proprietary ITS systems
- Lack of expertise and technical support
- Systems that are not capable of organizationwide data sharing
- Poor or undeveloped relationships and communication between IT departments and other departments
- Business practices and structures that have not adapted to the emerging ITS environment and lack direction

To varying degrees, all the transit agencies surveyed in 2005 were dealing with one or more of these constraints. Most of the problems carry over from those identified in an earlier survey of larger transit properties (Boldt 2000), which foresaw difficulties in accommodating expanding deployment of ITS technologies within the prevailing IT environment. Addressing these constraints will require planning, time, effort, and resources as each organization evolves its IT function. The following outline of a data architecture and strategy is intended to provide an overall direction for properties that are facing these problems.

Enterprise Data Management

This section provides general direction and guidelines for organizing ITS and other data to be used by practitioners. It defines an enterprise or an organizationwide approach. The guidelines follow general data management principles and provide a suggested architecture that has been discussed in the transit literature. Among the Guidebook's case studies, Tri Met serves as a good example of a transit organization that has developed an enterprise data management architecture.

A first step in enterprise data management is to develop a database design. The database design is a detailed plan for organizing and structuring data maintained across the organization. This is also called a database schema, with depictions of how the data are diagramed and charted.

There are several reasons for developing a database design. Database designs facilitate organizing, storing, retrieving, and sharing the information across the organization. Basically, the database design shows how the whole organization will use, share, and sustain data over time when incorporated into database software. In order for a computer system to receive information from ITS or other systems, and process data in a consistent manner, the data that it receives from one or more places must be defined. The data must be defined such that the computer system knows what a data field means, in what format the data is stored, and where it should store results. This is the purpose of a data model; it defines the organization of the information such that systems can understand what data resides therein, where it resides, how it is stored and how the data are related. Data models not only allow data sharing, they allow computer systems to work together. Fundamentally, the data model definition and how well the data model is defined will determine how well a computer system operates and how well it can share data with other systems and business domains. It is essential to define a well functioning database in order to write applications to address business problems. If a data model is not well defined, efforts to computerize problem solving or to implement business improvements will likely be difficult and expensive, if not impossible.

The process of defining a data model passes through three stages:

- Conceptual definition
- Logical model
- Physical data model

Conceptual definition consists of diagramming the data and relationships among the data to be stored. It is a starting point for organizing the data. A logical data model finalizes entities, fields, and relationships as tables, columns, relationships, and constraints. Given a logical data model, a physical database model can be created in a commercial database software product, such as Oracle or Sequel Server.

Fortunately, in defining a data model, there are commercially available data modeling methodologies, computerized tools (e.g., computer-aided software engineering [CASE] tools), and an experienced skill set to facilitate the development. Even with commercial off-the-shelf (COTS) software products, designing a data model can take significant time. Depending on which methodology and tool(s) are chosen, starting at the very beginning involves first defining a conceptual model, then a logical model, followed by a physical model. However, given the industry examples, rarely does the process of defining an enterprise data model start from scratch with the conceptual model. Much work has already been performed in defining "starting point" models that can be used as inputs to defining an enterprise transit GIS-ITS-enterprise data model. Examples of these starting points are listed as follows:

- GIS vendors publish industry standard models defined by consortiums. For example, ESRI public models include land, transportation, and address models (ESRI 2007).
- Most IT organizations will have staff expertise and CASE tools to assist in developing data models.

Since the process of designing an enterprise data model does not have to re-invent the wheel, a transit agency can benefit from what has been defined and proven in previous efforts. A typical approach in using existing models is one where the data maintained and used by an organization's current and future processes (as foreseen or as defined in a "to-be" model) are compared with the starting point model(s). Gaps in what is defined in one or more of the starting point models are addressed as needed to define the target data model. This process is called "gap analysis." Other inputs to the gap analysis process are the data requirements for existing or planned computerized systems.

The enterprise data model design and system integration process must have a clear definition of the extent, or scope, of the data and systems that will initially be contributing and using data from the enterprise data model. In addition, the process needs to consider the data requirements of other business areas that will be included in the future. If a well-defined and bounded scope is not established, the data modeling process would stretch out indefinitely.

It is best to start an enterprise data and system integration process/project involving a limited set of business areas in order to prove the model and the integration methods prior to rolling the enterprise data model and associated system integration into other areas of the organization. In other words, "start small and smart." For example, an initial scope for an enterprise data model and system integration project could be defined as one that includes a subset of ITS data systems, GIS, and the use of ITS and GIS data by marketing personnel. In addition, the scope would include the impact of the enterprise definition on other business units currently using ITS systems and GIS, such as Operations.

Database Design and GIS Data

Typically GIS data are also stored in an enterprise or relational database management system (RDBMS). GIS information, which is spatial in nature and robust in size, requires special consideration as a major aspect of the database design. In the GIS arena, physical entities are defined as objects with attributes, relationships, constraints, and behaviors. Most GIS objects have spatial characteristics: geometries (points, lines, or polygons) and network topology. The network topology defines what object is connected to what other objects, as in a street network. In a street network, for example, the GIS database and spatial data manager knows that Main Street intersects with 1st Avenue at a specific location. A GIS supports the application of geometric functions (e.g., union, intersection of spatial objects). For example, a GIS can determine the spatial relationships of boundary objects, such as how many stops are contained within a particular zone.

Enterprise data that are typically stored within a GIS include the objects and their corresponding data plus a "land base" that provides a base map, which serves as a foundation on which transit-specific information can be overlain. Examples of data typically found in a land base include

- Streets and a street network;
- Aerial photography;
- Elevation contours;
- Buildings;
- Boundary data: zoning, blocks, states, county, tax, zip codes, lots, parcels; and
- Census boundary information and census data.

Combining ITS information and GIS information in the same database allows the ITS data to be related and analyzed by location. It should be noted that location values are defined in a specific coordinate system. If two or more systems contributing data to an enterprise database contain location coordinate values defined in different coordinate systems or projections, the differences can be reconciled with coordinate transformations or on-the-fly projections.

An object in an enterprise data model may have attributes that are defined in multiple systems. In order to relate all pieces of information about a specific object/entity from multiple systems, a common identifier is critical. A common identifier uniquely identifies one occurrence of an object from every other occurrence. The identifier may be made up of one or more fields in a database. For example, a stop location has an identifier that distinguishes it from all other stop locations.

Given the spatial and object-oriented nature of GIS and ITS data, integration of the two offers a great opportunity for analysis. In addition, other external databases can be linked to an enterprise database for graphic display or analyses (e.g., census data, demographic datasets, or address data). Marketing may also have other data sources, currently used solely for their purposes, that have a "locational" characteristic that can be integrated with ITS and GIS data and provide the capability for analyses.

The broad capabilities available with GIS spatial analysis tools and the data supplied by ITS technologies are ideal for application in the marketing arena. Some of the geographic and/or graphic analysis capabilities that a GIS can provide are

- Thematic presentation,
- Spatial overlays,
- Proximity analysis,
- Point density visualization,
- Customer location,
- Event or incident analysis,
- Market segments or characteristics, and
- Direct mail marketing.

Using the Database

The actual data model is structured within commercial RDBMS. The RDBMS serves as a repository for the data, as an analytical tool for retrieving information, and as a mechanism for exchanging data between systems.

Several of the ITS systems produce information in the format of a RDBMS. This allows data, after validation or post-processing, to be transported into the RDBMS for storage and analysis. GIS systems use the RDBMS as a storage and retrieval mechanism for data as well. In itself, the RDBMS can serve as a powerful standalone tool for retrieving ITS information and analyzing marketing data. When combined with GIS, it is a very powerful tool that can map the data as well.

The main drawback with using these powerful tools are they are not "casual user" friendly and typically take considerable technical training or trained staff to manipulate the data. Most of the transit agencies interviewed in the course of selecting the case study properties for this Guidebook were hiring or cultivating their own staff to orchestrate both RDBMS and GIS in an attempt to "get at the data." Other agencies were relying on their IT staff to facilitate analysis of the data. The key challenge is how to be able to put this information in the hands of casual users, like marketing staff, without expecting them to become expert users or continually relying on a few expert users to produce the desired information.

The way to address this critical challenge is to develop applications for both the RDBMS and the GIS that provide menu driven applications to allow casual users to use the systems in a more "push button" environment. This approach will require working with IT or having technical resources set up this capability. A key objective should be to allow more people within the organization to access and analyze ITS data. Presently, the fact that these systems are expert systems has been a major constraint in getting the ITS and other data out to the people who can use it in the organization. ITS data will never realize its full potential if it cannot be used effectively by more people. At present, much of the market research potential of ITS data has been constrained, but could be leveraged significantly by making the data readily available within a data management architecture that facilitates additional users.

Architectures Supporting Data Integration

Once the data have been organized and stored in a database, an architecture that will automatically provide for the integration of data between various ITS and other systems can be defined. A database architecture, like a data warehouse, can provide for automated data collection, storage, archiving, and retrieval. This prevents the need for manual loading of all the information and ensures that current data are available. While this architecture takes some expertise and effort to set up, it will pay dividends to the users and also ensure a more sustainable system, costing less in the long run and saving the time and effort of continually loading data.

The intent of this section is to provide an overview of database architectures that support enterprise data. It will present examples of the most common types of data transactions and how they are set up in relation to data architectures, such as data warehouses and data marts. Several database management terms will be used throughout this section. Defining the terms up front, as well as in context, may be helpful. Various definitions exist for these terms. However, for the purposes of this section, the following definitions are used:

- Data Mart—a database that is most likely a departmental database that was designed to support a particular business function. Usually, each department or business unit is considered the "owner" of its data mart, and they provide for maintenance of the data. This enables each department to use, manipulate and develop their data, without altering information inside other data marts or the data warehouse.
- Data Warehouse—a collection of individual databases across departments and business functions, specifically structured for organizationwide access to the data. The term "enterprise database" is analogous to data warehouse.
- Data Repository—a common term and, for the purposes of this section, no distinction is made between a data warehouse and a data repository.
- Federated Database—a federated database is much like a data warehouse except that the implementation of the federated database integrates multiple autonomous databases into what looks like a single database. A federated database implementation provides a front end interface that stores or retrieves required data from all source data marts using a single query. While this is an option and has advantages for some organizations, it is not discussed here as a mainstream option for transit agencies due to the level of technology required for construction and sustainability. The definition is included because it is discussed in the transit literature.

Using ITS, GIS, and marketing data sources, proprietary databases and Relational Database Management Technology as examples, an enterprise database or a data warehouse can be set up designed from components such as the following:

- Proprietary database(s) implemented as a set of files or defined within RDBMS BLOB for System A. BLOB (binary large object) is another storage mechanism for files with in the RDBMS.
- Open database implemented within RDBMS for System B, which is an ITS system.
- System C, which is a RDBMS ITS system, produces copious amounts of time-based data, which is stored in a database.
- A GIS spatial database implemented in RDBMS with a spatial database manager "on top of" RDBMS (e.g., ESRI's SDE [spatial database engine] or Oracle Spatial technology).
- External datasets supplied in relational tables or flat files with known record definitions. This could be census data, addressing data, or customer data.
- Systems that are considered to maintain and house confidential data or secured data in their databases (data marts) in proprietary or open database technology.

Since System A has a proprietary database, data from System A will need to be exported or requested from System A in order to feed an enterprise database. In this case, there would be duplicate data—data stored in the proprietary data mart and in the data warehouse. In cases like this, as well as others, clear data ownership needs to be defined amongst the enterprise user base. If more than one system needs to be able to update attributes or define new entities, then a complex data update process needs to be defined. Since many of the ITS systems are proprietary and support their own data structures, data will need to be duplicated and organized in a format for enterprise use.

In the case of ITS System B, its data mart is already in an open database platform (e.g., Oracle). If properly defined and of the necessary quality to support the enterprise database, System B's data may be logically defined as part of the enterprise database without duplicating the data. This approach works for ITS systems that are proprietary, but offer the ability to report out data to RDBMS.

In the case of ITS System C, massive amounts of data are produced and used by department(s). The data in System C may not necessarily be directly defined as part of the enterprise database, even if it resides in RDBMS. The enterprise organization may not require the retrieval of the specific data stored in System C. To support the enterprise, data from System C's data mart may need to be processed or summarized and then exported to the enterprise database for use by other units, such as marketing. One example would be AVL data. Typically marketing would not want all the AVL data because of the database size and its organization for operations. In this case, marketing would get summaries of the information they do want versus sorting through reams of data to pick out what they want.

In an enterprise GIS implementation, and depending on the GIS technology, GIS data can be stored in an enterprise database, such as Oracle. However, to satisfy business requirements of a GIS (e.g., versioned data, spatially indexed data) and to perform GIS analyses on the spatial data, a spatial database manager must store and retrieve the data owned by GIS. Other databases (e.g., event data from mobile data recorders) can be linked to the GIS so that it can be analyzed with spatial functions.

External datasets residing in Oracle or other enterprise database technologies can be integrated into the enterprise system much like System B's data. Census or addressing data are examples.

Data contained in confidential systems (e.g., customer billing data) or in systems needing secure access (e.g., financial or accounting of fare revenues) will need to be extracted or requested from those systems and stored in accessible tables in the enterprise database. This way the whole database of the confidential system is not being used or entered in any way.

Using these components, the enterprise database would consist of the inclusion of some system's data marts, data extracted from other system's data marts, RDBMS resident data from some systems, and spatial data from GIS. The resulting enterprise database can be defined as the enterprise data warehouse, the combination of many different databases across an entire enterprise. Figure 4-1 depicts the methods for populating the data warehouse using these examples.

Access to the Data in the Warehouse

Data can be written to, read from, or updated in the data warehouse using various methodologies. Systems can integrate with the data warehouse using various methods.

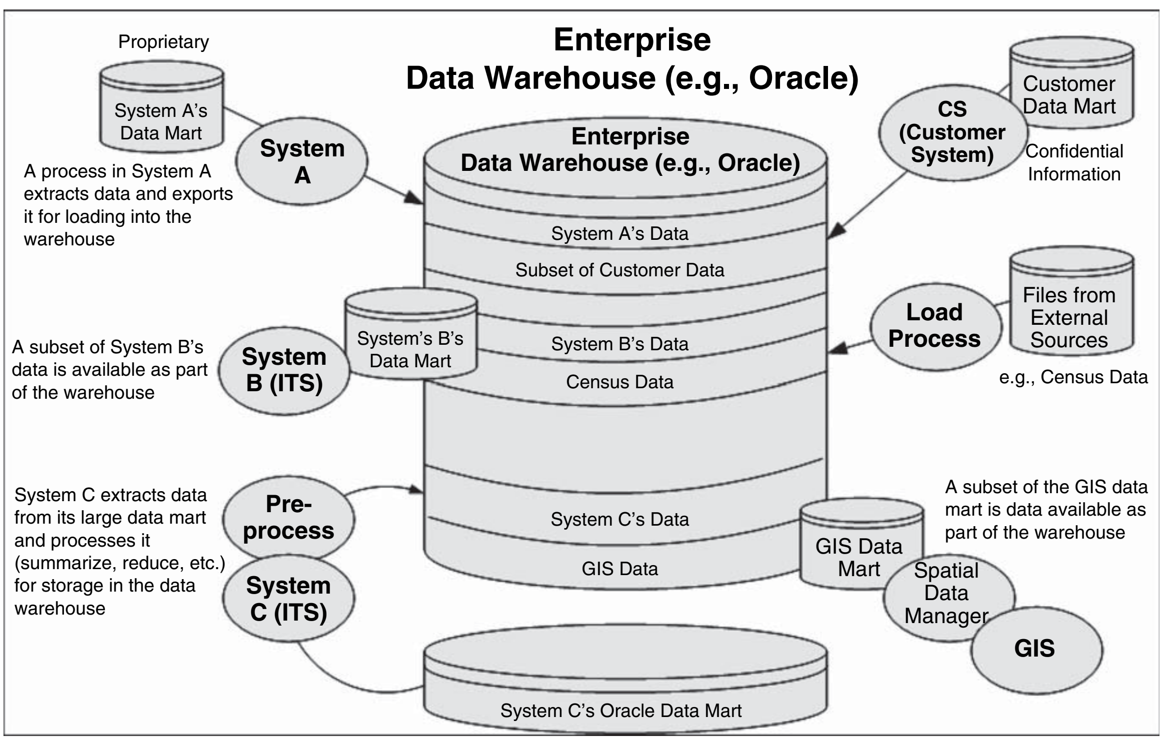

Figure 4-1. Population of the data warehouse.

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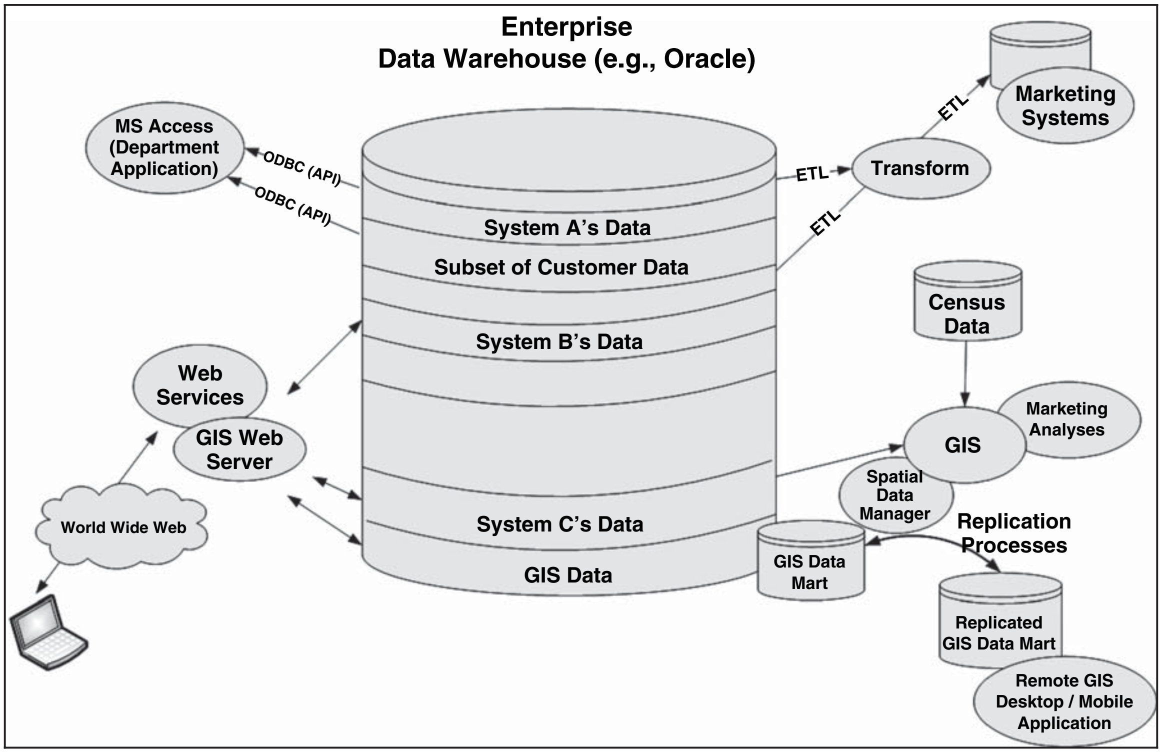

Figure 4-2. Data access and integration.

Data Oriented Integration Techniques

- File transfer
- Extract, transform, and load (ETL)
- Data replication

Software or Service Oriented Integration Techniques

- Web services
- Remote procedure call integration/application programming interface (RPC/API)

File transfers are simple data exchanges where a file from the source data mart is directly consumed by the target database/data warehouse, or the source system writes a file in a specific format for the target database/system to consume. In some cases, the source file is copied and placed in another location for the target system to use.

The ETL method uses data extraction from the source data mart, processing of the data to transform it into the format expected by the target system, and then loading the resulting data into the target database.

Data replication involves a more sophisticated source and target database management system. The data in the source system can be replicated for use in a target system. Updates to the data can be made in both systems. Changes originating in one system will be synchronized in the other.

Web services can be written which access the data in the warehouse as needed by web users. The web interface and web services are designed such that the data organization and required access are hidden from the web user. Web services logically unify disparate data sources where necessary.

RPC/API integration involves one system that supplies information via a call from another system. RPCs and APIs define how external applications can call a system and specify what information it wants returned from the system. RPCs and APIs are often provided by a commercial application and can be provided by custom applications.

Each integration methodology has advantages and disadvantages. In practice, multiple methods will often be used to interact with the data warehouse or with specific source/target systems that participate in the warehouse. Figure 4-2 depicts various data access methods using the data warehouse as a central repository.

Implementing Enterprise Data Management and Integration

This section describes a strategy and a process for data management and integration that will result in more and better data being available for marketing and other functions within the organization. Following this strategy would benefit most of the transit organizations interviewed and would

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allow greater leveraging of ITS data. Developing an enterprise data strategy requires resources, planning, time and expertise on the front end, but will result in overall savings over time by providing a sustainable system that allows more people to access better data without forcing practitioners to become expert users or hiring more technology staff to support daily efforts.

Ideally, the departments within a transit organization would work with their IT department to enlist the expertise needed to construct an enterprise data strategy. The overall goal in presenting an overview of enterprise data management has been to sketch a set of general guidelines and to outline the tasks and issues involved. End user departments will need to assist in specifying the relevant data and uses for that data. Typically, success requires a joint effort of users and IT professionals.

ITS Data Validation

To ensure accuracy and integrity, ITS data recovered from on-board systems must be validated before being forwarded to the enterprise data system. An essential task in this process involves matching vehicles' AVL data records to their schedules and the base map of stops and time points associated with assigned work. Selected event data recorded at locations other than those represented in the base map must also be assigned to base map locations. Examples of such events include instances where a vehicle drops off or picks up passengers between scheduled stops, records for temporary re-routes, the record of a vehicle's maximum speed between stops, or a non-stop event record reported by a mobile data terminal or electronic registering farebox. Data are also screened to identify extreme values, which may indicate a malfunctioning unit. Records with extreme values are retained, but flagged to indicate that the data are suspect and may be unusable.

Validation of passenger loads and boarding and alighting count data from APCs is especially important, given the need for accuracy of these data in meeting external and internal reporting needs. For passenger loads, a procedure must be in place to "zero out" the totals at defined service junctures, ranging from the conclusion of a vehicle's daily assigned work to the completion of each trip. A routine must then be implemented to proportionately adjust boarding and alighting data to be consistent with the passenger load zeroing adjustment (Furth et al. 2006).

It is worthwhile to verify the accuracy of the actual boarding and alighting counts recorded by APCs, in the system acceptance process and periodically thereafter. Some properties test accuracy by comparing APC counts against those recorded by ride checkers. The maintained assumption that ride checker counts are error-free is a strong one, however. An alternative to reliance on ride checker counts was used by Kimpel et al. (2003), who compared boarding and alighting counts recorded by TriMet's APCs against counts recorded by on-board cameras directed at vehicles' doors.

Given verification of the accuracy of APCs, this system can then be used to assess the accuracy of other on-board systems. For example, the CTA intends to check transaction summaries recorded by its smart card, magnetic card, and electronic registering fareboxes against corresponding APC counts.

Operator-keyed data from electronic registering fareboxes and mobile data terminals are probably subject to the greatest amount of error among on-board systems in terms of documenting the actual incidence of represented events. The transit literature does not report attempts to validate event data, although analysts at the case study properties noted that they were wary of interpretations where event data are treated as "ground truth."

There are several possible ways of assessing the validity of operator-keyed event data. One would be to assign "silent shoppers" to a sample of trips to record selected events, and then compare the manually recorded data against the operator-keyed data. Another approach that would likely improve validity would be to develop a data screening process to identify instances where multiple specific events are keyed at the same time or location, recognizing that in some cases (e.g., fare evasions) multiple events can be valid. However, the operator training process probably offers the best opportunity for ensuring the validity of event data. In this setting, it can be emphasized that recording events is not simply a part of the job; rather, it is providing information that can often be used to improve the conditions of operators' assignments, including their safety and security.

In the customer service area, ITS data can be applied beyond its common use in validating customer complaints. For example, actual arrival time data from AVL can be compared to arrival times predicted by real time arrival software to assess the accuracy and reliability of the predictions (Crout 2007). Such analysis can also contribute to determining how far out arrive time predictions can be accurately and reliably made.

Reporting and Analysis Tools

Reporting and analysis tools drawing on archived ITS data can be grouped into three categories: those developed by the ITS vendor, those developed in-house, and those developed by a third party software vendor.

ITS vendor developed reporting software is available for ticket vending machines, electronic registering fareboxes, and AVL and APC systems. The software for ticket vending machines and fareboxes report transactions data, as described in Chapter 2 of the Guidebook. Farebox software can also report operator-keyed events for systems that include this functionality. Furth et al. (2006) conclude that farebox reporting software is very inflexible, and that properties desiring to use farebox data to monitor ridership have to first export data from the farebox system to a database developed in-house in order to structure reports.

Vendor developed performance reporting software for AVL-APC systems is a fairly recent addition to the transit industry. This software is in use among properties of varying size, but appears to be especially welcomed by smaller properties with limited IT resources. Previously, vendor-provided AVL reporting software was limited to data "playback" routines that were useful for investigating incidents and customer complaints, but had very limited capability to support offline performance reporting and analysis.

More generally, the development of reporting software by ITS vendors reflects a change in their role in the technology life cycle. As Furth et al. (2006: 71) observed, in the initial phase of advanced technology deployment in the industry, technology vendors viewed their principal role as being providers of hardware, and "their job ended when they handed the transit agency the data." Whether the data could be rationalized and transformed into desired reports was an issue that was usually left to the transit property to resolve. Consequently, in the 1990s era of ITS deployment, many properties struggled to produce useful performance reports (Casey 2000).

The most important of the vendor-developed reporting packages covers data from AVL and APC systems. An example summarizing weekday service delivery performance on the Denver Regional Transportation District's South Broadway route in October 2005 is shown in Figure 4-3. The report provides information that operations managers usually track in assessing service delivery, including on-time performance, boardings per mile and hour of revenue service, and actual average speed compared to schedule speed. Passenger activity is also reported by service period, and data are sorted to identify to most heavily used stops. Sorting by performance category (boardings per revenue hour in this example) can produce rankings among scheduled trips. Finally, performance for selected trips is reported.

Vendor-developed reporting software is very useful for communicating performance information at the managerial levels of the organization. Its data querying capabilities beyond this important function, however, are limited. Thus, some properties have developed more flexible performance reporting systems in-house. It should be noted that in-house reporting systems were often originally developed out of necessity and were mostly confined to larger properties where staff with the necessary advanced database querying skills were in place.

The main advantage of the reporting systems developed in-house is that they can be structured to produce performance indicators of specific interest to the agency. Moreover, as interests in specific aspects of performance evolve, the reporting system can be readily modified to evolve in tandem. Generally, the data queries programmed within in-house reporting systems can be structured to address virtually any question represented in the space-time-customer dimensions of the ITS database.

TriMet's experience with its in-house reporting system is approaching the 10-year mark. The system is considered to be among the most comprehensive in the transit industry (Furth et al. 2006), and its periodic performance reports include indicators that have been designed to correspond to service delivery attributes that the agency's satisfaction surveys have found to be important to customers. An example is shown in Table 4-1.

TriMet surveys found that reliability issues were the second most important source of dissatisfaction among bus riders (after frequency of service issues). Table 4-1 provides information on three alternative reliability measures. The first, on-time performance, is the transit industry's traditional measure of reliability. The second, headway adherence, reports the percentage of trips that maintain an actual headway that is within 50% of the scheduled headway. This proxy measures the spacing or regularity of service. The third reliability proxy, excess wait, measures the additional time a typical rider would spend waiting for a bus given the actual headway deviations documented in the AVL data.

The three measures of reliability often correspond, but not always. For example, the Route 64-Marquam Hill achieves high marks for on-time performance and headway adherence, but fares much worse on the excess wait measure. The same is true for the Route 51-Vista. It could be argued that the excess wait measure best represents a rider's view of reliability. However, the choice of indicator could just as well be informed empirically by relating the variation of each indicator over the routes in the system to the route variation in surveyed satisfaction. In this case, the "best" customer-oriented measure would be the one that most closely corresponds to riders' reported satisfaction.

Reporting and analysis software developed by third party vendors range from fairly elementary packages that document Web and automated telephone system activity to more advanced packages that support statistical and spatial analysis of data extracted from an enterprise database. Data recovered by Web and automated telephone system monitoring software are described in Chapter 2 of the Guidebook.

In their most elementary applications, statistical software packages allow researchers to logically summarize ITS data and report patterns and trends. More advanced applications involve estimation of systematic relationships among ITS data elements within user-defined contexts. An important feature of a statistical software package is its ability to easily

Regional Transportation District — **Ridecheck Plus**

0: SOUTH BROADWAY - N-Bound

Weekday Route 0 Oct05 - Average — Gross Trips 1,874

Vehicle Trips	138	Boardings Per Mile	3.89	TP Ontime	816
Boardings	4,006	Boardings Per Hour	62.4	TP Early	138
Revenue Miles	1,030.2	Schedule Speed (MPH)	8.7	TP Late	120
Revenue Hours	64.2	Actual Speed (MPH)	8.4	Ontime (%)	76.0

Selected Trips

	First Trip	Maximum Boardings Trip	Maximum Load Trip	Last Trip
Time	12:25 AM	2:56 PM	2:56 PM	11:37 PM
Serial #	3095829	3095787	3095787	3095886
Trip #	2	184	184	276
Max Load	6	34	34	3
Boardings	10	87	87	4

Time Period

Period	Trips	Board	Per Trip Avg Board	Per Trip Max Load
AM Early	10	245	24.5	24
AM Peak	27	777	28.8	27
Midday	56	1,928	34.4	34
PM Peak	16	512	32.0	23
PM Late	23	489	21.3	19
Other	6	55	9.1	9
All Periods	138	4,006	29.0	34

Top 10 Stops By Boardings

Stop	Dir	Board	Alight	Load
I-25/Broadway Station	E	408	209	1,139
S Lincoln St/Alameda Ave	N	255	55	1,271
Lincoln St/1st Ave	N	223	77	1,631
Lincoln St/7th Ave	N	193	96	1,904
Lincoln St/4th Ave	N	175	51	1,757
Lincoln St/9th Ave	N	174	129	1,950
Lincoln St/Ellsworth Ave	N	161	41	1,485
Highlands Ranch Town Ce	S	158	54	104
Englewood Station	N	147	226	373
Lincoln St/11th Ave	N	116	128	1,936

Top 10 Stops By Alightings

Stop	Dir	Board	Alight	Load
Colfax Ave/Broadway	W	34	983	906
Welton St/16th St	N	23	363	460
Englewood Station	N	147	226	373
17th St/Market St	S	6	214	7
I-25/Broadway Station	E	408	209	1,139
Lincoln St/13th Ave	N	52	133	1,852
Lincoln St/9th Ave	N	174	129	1,950
Lincoln St/11th Ave	N	116	128	1,936
15th St/Cleveland Pl	N	5	99	807
Lincoln St/7th Ave	N	193	96	1,904

Top 10 Trips By Boardings

Serial #	Time	Route	Rt Dir	Board	Alight	Max Load	Board Per Mi	Board Per Hr	Actual Speed (MPH)	Sch Speed (MPH)	Ontime (%)
3095787	2:56 PM	0: SOUTH BROAD	N	87	87	34	6.38	56.4	8.4	8.8	71.8
3095810	2:25 PM	0: SOUTH BROAD	N	82	82	24	6.01	54.0	8.7	9.0	85.9
3095789	3:26 PM	0: SOUTH BROAD	N	71	71	28	5.17	45.1	8.6	8.7	64.6
3095765	3:56 PM	0: SOUTH BROAD	N	70	70	27	5.09	44.3	8.3	8.7	67.4
3095763	11:56 AM	0: SOUTH BROAD	N	69	69	25	5.05	46.8	8.8	9.3	71.3
3095814	1:25 PM	0: SOUTH BROAD	N	61	61	22	4.50	40.3	8.9	9.0	71.0
3095766	4:26 PM	0: SOUTH BROAD	N	60	60	22	4.38	39.3	8.3	9.0	78.9
3095768	5:29 PM	0: SOUTH BROAD	N	59	59	18	4.33	41.8	8.8	9.7	73.1
3095806	11:26 AM	0: SOUTH BROAD	N	55	55	22	4.01	37.0	8.7	9.2	63.9
3095863	9:27 AM	0: SOUTH BROAD	N	52	52	19	3.83	36.8	8.9	9.6	79.6

17-Apr-06 — ***Composite Statistics*** — *Page 1 of 4*

Figure 4-3. Summary route performance report from vendor-developed software.

extract data from an agency's ITS database. At TriMet, researchers in the operations division use statistical analysis software (SAS) for advanced analysis of ITS data. The main advantage of this package is that its programming features allow analysts to directly query the Oracle data tables in the agency's enterprise data system and create data records that can then be easily imported for statistical analysis. Another advantage of this software package is its extensive graphing capability, which supports more effective communication of trends and patterns.

An example report from TriMet illustrating SAS graphing features is shown in Figure 4-4. This report is produced for

Table 4-1. Headway adherence and excess wait time, spring 2007 (sorted by excess wait time).

Route, Direction, Time of Day	Daily Trips	On Time	Early	Late	Scheduled Headway	Headway Adherence	Excess Wait (min.)
8-NE 15th Ave - Outbound – PM Peak	14.0	45%	3%	52%	8:58	48%	3:27
4-Fessenden - Outbound - PM Peak	10.0	46%	4%	50%	12:37	49%	3:27
15-Belmont - Outbound - PM Peak	20.0	63%	2%	34%	6:14	49%	3:15
8-Jackson Park - Inbound - PM Peak	15.0	57%	1%	42%	8:19	47%	3:10
96-Tualatin/I-5 - Outbound - PM Peak	10.0	60%	0%	40%	10:57	67%	2:47
64-Marquam Hill/Tigard TC - Inbound - AM Peak	5.0	96%	0%	4%	19:50	90%	2:43
4-Division - Outbound - PM Peak	15.0	65%	6%	29%	7:58	54%	2:33
4-Division - Inbound - PM Peak	10.0	67%	4%	29%	12:43	59%	2:23
51-Vista - Inbound - AM Peak	8.4	89%	8%	2%	17:05	91%	2:11
20-Burnside/Stark - Outbound - PM Peak	7.0	66%	6%	27%	15:14	75%	2:07
17-Holgate - Outbound - PM Peak	11.0	59%	7%	33%	11:00	65%	2:07
94-Sherwood/Pacific Hwy Express - Outbound - PM Peak	14.0	73%	0%	26%	9:21	66%	2:05
72-Killingsworth/82nd Ave - Inbound - PM Peak	16.0	73%	7%	20%	7:42	50%	2:02
99-McLoughlin Express - Outbound - PM Peak	8.0	86%	0%	14%	17:09	84%	1:59
17-NW 21st Ave/St Helens Rd - Outbound - PM Peak	8.0	42%	3%	55%	15:00	75%	1:51
15-NW 23rd Ave - Outbound - Midday	31.0	53%	8%	39%	13:27	65%	1:48
4-Division - Inbound - AM Peak	15.0	89%	2%	9%	7:48	59%	1:43
32-Oatfield - Outbound - PM Peak	6.0	74%	4%	22%	24:34	88%	1:43
9-Powell - Outbound - PM Peak	14.0	62%	7%	32%	8:03	64%	1:42
12-Barbur Blvd - Outbound - Night	19.0	64%	3%	33%	20:08	81%	1:39
71-60th Ave/122nd Ave - Inbound - Midday	27.0	82%	5%	14%	16:18	76%	1:39
15-NW 23rd Ave - Outbound - PM Peak	8.0	48%	8%	44%	15:00	70%	1:38
4-Fessenden - Outbound - Night	23.0	71%	5%	24%	19:52	83%	1:34
72-Killingsworth/82nd Ave - Outbound - PM Peak	16.0	80%	5%	15%	7:43	58%	1:34
8-Jackson Park - Outbound - Midday	32.0	71%	3%	27%	13:11	80%	1:33
15-NW 23rd Ave - Outbound - AM Peak	22.0	72%	5%	24%	5:42	49%	1:33

operations managers, with the tables containing weekly performance statistics and the graphs showing longer term patterns and trends. In this instance, previous statistical analysis had determined that the incidence of bus bunching in the system was strongly related to late pullouts from garages and late departures from route terminals following layovers. The trend improvements in late pullouts and departures shown in the figure suggest that the reports have served their purpose in focusing the attention of garage managers and field supervisors on the attendant problems.

The transit industry's use of GIS for spatial analysis of ITS data and for related mapping of service delivery and market phenomena is evolving. A 2003 survey found over 75% of responding transit agencies employing GIS in a broad range of applications (Sutton 2004). Advances in the use of GIS in the transit industry parallel the emergence of the more general field, GIS for Transportation (GIS-T), that has developed advanced applications in transportation research, planning, and management (Thill 2000, Miller and Shaw 2001).

According to Sutton (2004), there are three levels of GIS integration within transit organizations, distinguished by the level of applications that must be supported: (1) specific *project* applications; (2) use as a *departmental* resource in support of established practices such as planning, scheduling, and real time bus operations; and (3) use as an *enterprise* system where GIS is incorporated into an agency's information technology (IT) infrastructure. Over time, the trend in GIS architecture has evolved in the transit industry toward enterprise level systems, managed within the IT environment and coordinated with the management of an enterprise database. As explained earlier in this chapter, with a well-designed data model relating transportation features and attributes to ITS data tables, agencywide access to archived data for GIS applications is ensured.

Institutional Issues

The overall organizational structure and management philosophy have direct impacts on the ability of a transit agency to leverage ITS data for market research. An organization that is characterized by a lack of cross-divisional cooperation or is less open to change will need stronger leadership to create an environment where ITS data can be effectively integrated into agency functions. Similarly, if an agency has not yet made the shift to customer orientation using market research, the organizational structure will not be present to take full advantage of the benefits of ITS data. This section examines the institutional issues surrounding successful ITS implementation with respect to leveraging ITS data for market research.

Focus on the Customer

The transit industry has seen a surge in the focus on customers, with many properties citing this as the reason behind ridership success in recent years. *TCRP Report 111*, "Elements

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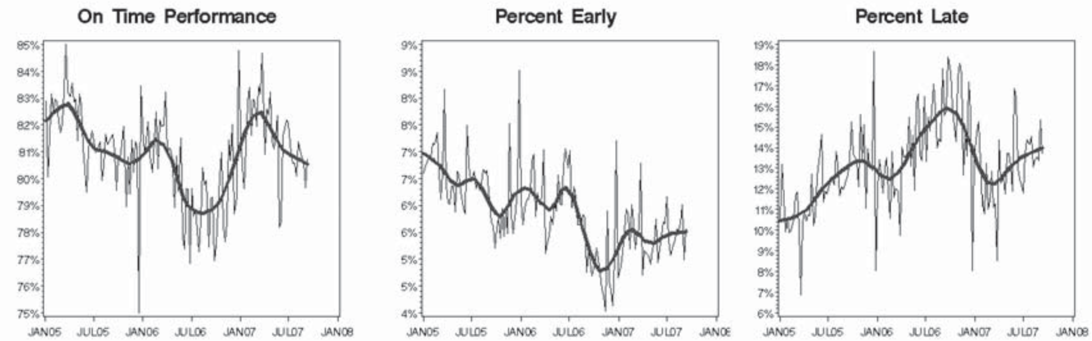
Weekly Operations Trend Report: TOTAL

	07/29/07	08/05/07	08/12/07	08/19/07	08/26/07	09/02/07	09/09/07
On Time Performance							
On Time	80.1%	81.4%	81.0%	80.8%	80.6%	79.7%	80.7%
Early	5.4%	5.6%	5.5%	5.7%	6.0%	5.0%	5.6%
Late	14.6%	13.0%	13.4%	13.6%	13.4%	15.3%	13.7%



	07/29/07	08/05/07	08/12/07	08/19/07	08/26/07	09/02/07	09/09/07
Pullout Late From Garage	2.4%	2.1%	2.4%	2.8%	3.4%	4.4%	2.2%
Leaving End of Line Late							
3+ Minutes Late	11.1%	10.6%	10.7%	10.9%	11.1%	10.0%	9.9%
Number of Missed Pullouts	21	6	17	9	17	4	15
	0.52%	0.15%	0.42%	0.22%	0.42%	0.10%	0.37%

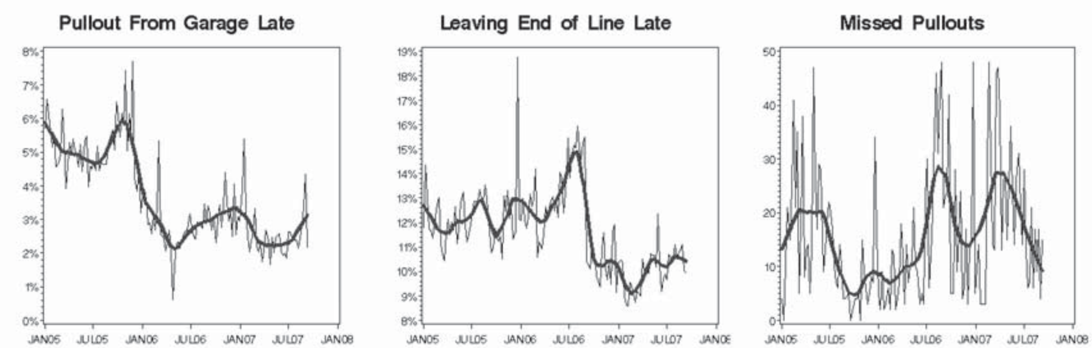


Figure 4-4. Graphical presentation of service delivery information at TriMet.

Needed to Create High-Ridership Transit Systems" (TranSystems et al. 2007) summarizes the successful marketing efforts pursued by transit agencies. Yet the survey conducted for this Guidebook revealed that few agencies have market research programs that rigorously analyze customer needs and expectations. Those with strong research programs are typically larger properties, such as New York City (MTA-NYCTA), Chicago (CTA), Washington, D.C. (WMATA), San Francisco (BART), and Portland (TriMet). For many properties, market research is confined to ridership counts and customer service activity addressing complaints and suggestions. ITS data can leverage market research, but only when that function is fully developed.

Thus, there is still a need for transit industry top management to become active supporters of market research, by requiring decisions to be made based on customer research, and by providing funding to conduct the needed research. This will require two levels of commitment: (1) funds to hire research firms that can provide project development, fielding, analysis, and/or report writing; and more important, (2) knowledgeable in-house staff that understand the transit business and specific project needs and oversee the activities of the consultant. By requiring customer understanding through market research, the transit industry can truly say it is customer oriented. The agencies will be able to take maximum advantage of traditional and ITS data sources and greatly increase their success in building ridership.

The case studies of CTA and TriMet (see Appendices A and C) document a level of commitment to the customer through an extensive market research program and demonstrate how ITS data can support and enhance the market research functions.

Role of Senior Management

Senior management involvement is critical to the success of integrating ITS with agency needs, ensuring that the resources and staff are there to support post-ITS deployment needs related to data management and end use analysis in market research. A key issue is to ensure that individual divisional priorities do not come at the expense of other agency needs. Operations, Marketing, IT, Finance, and other divisions need to be included from the initial planning of the systems to ensure that they understand the data potential and are involved in the development of the ITS and data management systems. An interdivisional team needs to be established that includes all potential users of the system. Senior management support is needed to ensure that the team does not ignore non-operational needs in the interests of expediency or cost savings.

Not only is senior management needed to ensure interdivisional teamwork, it is needed to support the budget requirements of the system. To effectively plan a system that can be used by all departments within the agency will require development of an enterprise database system, an agency activity that requires resources. Senior management's commitment is necessary to ensure that there are the resources to develop an enterprise database, provide the system requirements to store the vast amounts of data produced by ITS, and provide the ongoing technical staff to develop and maintain the enterprise data system.

A unique cross-competency exists with Madison Metro's general manager, who was directly involved in ITS procurement for the state. This experience allowed him to more effectively market ITS as a direct investment in customer service and improved operations. With that mindset at the top of the organization, it is likely that the agency is not simply seeking to use the data for market research as an afterthought, but more as a primary reason for implementing ITS.

Need for Interdepartmental Coordination

Transit properties typically enter the ITS arena through the purchase of operational systems, usually an AVL system to support bus dispatch. Other systems, such as APCs, are frequently purchased as an add-on to AVL. Because these systems are conceived in operations they are often specified, purchased, and deployed without involvement from the rest of the agency. This leads to a system that is isolated from other uses. Data are considered only in how they are needed for the originally intended task. The result is that data may be saved in a format that makes them of little use for marketers, or perhaps they are not saved at all.

Madison Metro's success represents a counter-example of the tendency to isolate ITS planning within operations. On fixed route bus service they have recently implemented AVL, APC, and magnetic stripe card systems on their fleet of 200 vehicles. The relatively flat organizational structure allowed the marketing department to be on a similar level as the transit department, which is in charge of operations and planning. Because the city and all its agencies are supported by the Information Service Unit, GIS has been integrated into transit ITS and market research data.

At the CTA, staff bolstered interdivisional cooperation with industry peer exchanges. They have interacted closely with TriMet and King County Metro through the U.S. DOT/FTA-sponsored Peer-to-Peer Development program (Gross et al., 2003). This program facilitates the sharing of best practices regarding transit use of ITS data and allowed CTA to learn from efforts at other transit districts, as well as share their own experiences.

Few, if any, transit properties in the U.S. have developed a service delivery analysis and monitoring capability comparable to what TriMet has achieved with its archived AVL and APC data. These achievements are a consequence of the forethought given to the specification of the data recovery and archiving features of their AVL-APC systems, the high penetration of APC units in the fleet, and the efforts of highly skilled staff analysts. Also, despite their organizational separation, market research and operations collaborated extensively in designing customer-oriented service performance measures for evaluating service delivery.

ITS Data Use and the Placement of Market Research Within the Institution

IT and Market Research are typically located in different divisions or departments within the organization. As such, market researchers are sometimes not included in the development of the data archiving architecture, and may not even know what data exist. Even when they become aware of the existence of ITS data, they may not have the skills to extract the data that could assist in market research activities. IT staff are typically assigned to tasks considered higher priority (e.g., operations support or financial systems) and provide market research support only as time is available. Two approaches to mitigating these impacts are described.

One approach is to create a data manager. The role of a data manager is to abstract and summarize data—making data available and legible for all users to understand and use. Potential users include the public, peer transit agencies, market researchers, and in-house groups. The need to find common ground for culling and presenting these data to the varied users makes decisionmaking capabilities and team-building skills desirable for data mangers, although these are not necessarily sought after in data-oriented positions. The data manager may want to create a collaborative process that ensures the needs of all users are met through ITS data collection—coordination with service planners, market researchers, analysts—to generate a comprehensive database that serves many needs.

The CTA provides a successful alternative approach, using technically savvy staff within the market research area to provide data support. When the case study was conducted, the CTA had been using ITS data for 3 years. Despite its large size, the CTA maintained an effective market research department with a staff comparable in numbers to smaller agencies. During the initial deployment of smart cards, AVL, and APCs, the CTA created the Data Services unit, which was responsible for post processing, merging data from various systems, and developing tools for data analysis. Recently, staff from data services was transferred to IT for the post-processing function, while several analysts remained in Data Services to conduct actual analysis. The effect of splitting these related job functions into separate departments is unclear, but CTA staff point to the data services unit as crucial in their success. They said it helped bridge the gap between the Management & Performance division (where IT resides) and market research staff.

Opportunities for Properties That Outsource Market Research Activities

ITS data analysis and market research are often viewed as activities that are only for larger districts, such as Portland and Chicago. Madison Metro provides an example of how a smaller agency with a lean staff can capitalize on the benefits of ITS for market research activities.

Madison has been successful in drawing on its ITS data to improve timetables and to identify a priority list of bus stop improvements and advertising opportunities based on stop-level passenger counts. In the 2 years since Madison implemented ITS on its buses, it has not yet fulfilled all the goals of the agency. Staff at Madison Metro seek to get a better understanding of the university student population and their trip patterns when school is in session. This understanding would help the agency better cope with the tremendous change in ridership numbers when school is not in session. The ridership numbers also support the negotiation of pass program agreements.

Another option that is especially applicable to small districts in university towns is to enlist the help of the educational institution. Interns can be a way to capitalize on the intellectual resources of nearby universities, although it must be recognized that such programs will require agency staff time to support the program. The investment can have a secondary benefit, however, in providing a potential pool of transit-savvy employees after graduation.

Improving the Use of ITS Data for Market Research

Once ITS data are archived in a database, it is a challenge to integrate the data into operations and market research reporting and decisionmaking. The CTA discusses other reasons for the ongoing success of its program. One is the series of "what's new" brown bag seminars that allow data services staff to show agency staff new applications and uses of data. Similarly, these seminars provide an open forum for staff to make requests so that data services has a better understanding of what is needed for the future.

Another positive aspect of Chicago's ITS approach is the formal relationship with MIT and University of Illinois-Chicago, through which CTA employs master's program interns. Those still in school are in the mindset to think critically about problems and help develop innovative approaches to solving them. In the same spirit, thesis students are brought on for two summers. In the first, they learn about the industry and agency while identifying an underlying problem and, in the second, they attempt to solve it in their thesis. This research develops innovative prototype applications of ITS data that can eventually evolve into adopted practices. This helps bridge the gap between innovation and implementation. The program is also a good source for qualified full-time staff candidates.

Staffing Issues

Bridging the Gap Between Market Research and IT

Two significant problems with ITS data are (1) the difficulty in integrating ITS data across different applications and (2) that ITS data are not easily exported to formats that can be analyzed in standard desktop software applications (e.g., spreadsheets). The inability to integrate data was cited as the top perceived barrier to using ITS data for transit market research in the industry survey conducted for the Guidebook.

ITS has the ability to enhance service and improve connections across departments within and external to the transit agency. The ITS Joint Programs Office of the U.S. Department of Transportation writes in its report, *Building Professional Capacity in ITS: An Assessment of ITS Training and Education Needs: The Transit Experience,* that ITS requires agencies to change their mission and approach to operations as advanced technology deployments become more interagency and systems-oriented. The report discusses internal barriers to effective use of ITS data, for example, being narrowly defined job functions and overall missions, as well as limited emphasis on funding for training and development. The report, released in 1999, recognized early on the difficulties of hiring and retaining qualified computer and systems engineers.

A critical element of the evolution toward integration of market research and ITS data is having staff that can bridge the gap between research and information technology. The role of a data manager is someone who is comfortable using information technology to draw from a number of sources of data and who can use datasets for a variety of purposes. Given the need for increased access of market researchers to the enterprise database, the role of market researcher should be expanded to include the functions of a data manager. From a staffing point of view, an ideal employee would be trained as a market researcher who is also capable of extracting data from proprietary sources for secondary analysis. A person who could satisfy these requirements would find several opportunities in what has been referred to in literature as "data management." IT and data management are related, but distinct. While IT personnel maintain computer networks and database systems, a data manager is concerned specifically with the data from ITS sources. These two positions are often confused within the transit environment and by transit agency managers, causing agencies to be hesitant or unwilling to hire what is mistakenly believed to be a second person to fill a data management position.

An institution must be willing to see the data manager as a viable addition to disseminate and target information based on new data, technology, and sources, and as a person able to create stronger internal and external networks. The role of a data manager should be defined and understood so that a relationship can be developed based on reasonable expectations rather than tasks outside the scope of a data manager's job description. Unfortunately, there is very often a lag between the time that ITS is deployed and the hiring of a data manager. A data manager is most effective when hired before data are defined or collected, which allows the data manager to facilitate the identification of optimal types of data and data collection sources. Ideally, a data manager, in conjunction with the agency staff and other stakeholders, will define the goals and objectives of the ITS system. However, as a result of technology often outpacing the ability for agencies to hire and utilize a data manager, more often the case is that data collection is already in process and the manager is hired later, giving this individual less opportunity to coordinate the different applications. In these situations, a data manager is limited in his/her ability to extract meaningful trends and performance indicators from data that were defined before he/she was brought on.

A transit agency attempting to better integrate a data manager into its institution should consider the role it wishes the manager to play, the opportunities it intends to provide, and the best way to integrate the manager into the agency. The importance of data management should not be overlooked, and the successful transit agency will see the hiring of a data manager as an investment in a more effective system in the future.

Recruiting and Retaining IT Staff and Data Analysts

Historically, it has been difficult for transit agencies to attract and retain IT staff. In *Research Results Digest Number 45,* "Identification of the Critical Workforce Development Issues in the Transit Industry," (TCRP 2001) both marketing and IT professionals are cited as difficult to attract and retain in the industry. Because IT is a secondary accessory to the transit industry (that is, not a core skill such as engineering, maintenance, and operations), many do not view the transit industry as a good choice for a place to pursue a career in IT. Another challenge to attracting IT professionals is the perception that there is greater potential for growth and income in other industries, especially in the private sector.

Some agencies have found the most effective means of retaining quality IT staff is by employing a "grow our own" strategy. Houston Metro uses this strategy, as discussed in *TCRP Report 77*, " Managing Transit's Workforce in the New Millennium" (McGlothin Davis and Corporate Strategies 2002), with the concept being that a transit agency will provide a fast-paced and exciting work environment that excels in providing new opportunities and job growth potential, focusing on retention and training rather than hiring specifically for a set of skills. The message that "employees will be involved in exciting work using up-to-date methods and resources" is reinforced by ensuring that "promises of interesting work and the use of state-of-the-art technology are kept." Additionally, offering regular in-service training will help to keep workers up-to-date and contribute to the feeling that the industry is progressing with technology. Other transit agencies have echoed the concern over attracting the highest level of employees for this profession, such as the Santa Clara Valley Transportation Authority, which stated in the same report that they strive to get the message out about having up-to-date technology and providing interesting work early in careers. Others have used salary incentives to attract high-level professionals, but this is limited in effectiveness for a potential employee who may have pre-conceived notions of the nature of the work being offered.

Another successful effort highlighted in *TCRP Report 77* is a program used by Metro-North Railroad called the "Integrated Approach to Recruiting, Training and Retaining Information Technology Professionals." In this recruiting program, "available positions were designed to be broader with more variety rather than a single task." These positions also include a job-progression calendar that projects upward movement opportunities and depicts the timeframes within which a good employee can expect to advance. Also, employees' opportunities to advance are not limited to managerial roles; they may instead become mentors and sources of technical knowledge for new hires. Benefits widely used in the private sector add to success, including flextime, dress-down day, and limited telecommuting. Among other rewards, top performers receive additional training.

CHAPTER 5

Lessons Learned, Issues, and Concerns

In 1997, TCRP convened a task group to explore strategic research initiatives that would guide fundamental change in the transit industry. In a future search conference, the task group developed a characterization of conditions in the transit industry that, in its assessment, represented a crisis (TCRP 1998). The crisis condition was seen to be a consequence of the industry's entrenched commitment to an "Efficient Transit Performance" paradigm organized around a command and control philosophy bound to a dependence on subsidy and a perceived inability to influence revenues. In contrast, the task group developed a vision of an alternative paradigm—"Change, Growth, and Mobility"—organized around a philosophy of shared responsibilities bound to a reliance on information and a commitment to customer service.

The outgrowth of the future search exercise was a commitment to fund a *New Paradigms* research initiative within TCRP. The first product of the initiative was *TCRP Report 53*, "New Paradigms for Local Public Transportation Organizations," (Cambridge Systematics 1999). Among other things, *TCRP Report 53* concluded that the transit industry needed to move beyond performance measures focused solely on operating efficiency to include measures ". . . that describe the attributes of the product (service) ***as perceived by the user***" (Cambridge Systematics 1999: 6-11, emphasis added). Implicit in this conclusion was the recognition that a greater focus on customers depended on a deeper commitment to understanding and acting on customer perceptions, preferences, opinions, and attitudes. In turn, this commitment would require a recasting of marketing beyond its traditional focus on customer relations and promotion to a more expanded mission that also embraced customer and market research.

Coinciding with the *New Paradigms* initiative, an accelerating technological transformation in the transit industry began delivering a vast amount of information about service delivery and customers. Although the industry's transformation from "information poor" to "information rich" status was clearly anticipated in the *New Paradigms* initial future search exercise, perspectives on how this information would contribute to a customer-oriented approach to service changed. Initially, the *New Paradigms* focus centered on tapping information technologies to develop new services for customers, with Web and phone-based trip planning software and real time vehicle arrival information serving as examples. Subsequently, the focus broadened to include operations information recovered from on-vehicle systems. These systems were clearly capable of producing information to support tracking service delivery performance, contributing to the efficiency objectives of the traditional paradigm. However, as was recognized in *TCRP Report 97*, "Emerging New Paradigms: A Guide to Fundamental Change in Local Public Transportation Organizations" (Stanley et al. 2003), much of the information from on-vehicle systems was not only customer-relevant, it could also be coordinated (in some instances, linked) with customer and market information to produce a more complete picture of the quality of customers' experiences. As envisioned in *TCRP Report 97,* this coordination would lead to performance assessment capabilities ". . . that bring into balance the quality of the customer's experience (the emerging strategic goal) and the efficiency with which resources are used (the production goal)" (Stanley et al. 2003: 2-4).

The perspective on coordinated applications of customer and market information with ITS data developed in *TCRP Report 97* represents the starting point for the present Guidebook. Overall, the Guidebook's purpose has been to illustrate how ITS data can be used in tandem with information recovered by traditional market research tools. In some instances, this involves applications where ITS data leverage or facilitate traditional market research practices. In other instances, this involves coordinating information from market and customer research with information from ITS technologies. And in a few instances, it involves a substitution of information provided by ITS technologies for information that had been previously obtained through manual practices.

The scope of the Guidebook goes beyond explaining how ITS data can be used to address specific customer and market research questions or cataloguing specific applications. As in the case of moving from the efficient performance to the customer-focused paradigm, the transition from traditional data collection to effective use of ITS data in customer and market research involves a number of intermediate steps and requires coordination across the agency. In the present case, the intermediate steps can be traced from technology acquisition to systems integration to data processing and management to the development of new reporting and analysis tools to staff development. This approach was considered necessary because early experiences indicated that information from ITS technologies was generally being underutilized in the transit industry (Casey 2000, Kemp 2002).

This chapter takes a technology life cycle approach to summarize the lessons learned from efforts to fold ITS data into customer and market research practices. In this approach, the life cycle is divided into four stages: (1) systems acquisition, (2) data management, (3) market research (or data analysis), and (4) decisionmaking. The four stages of the life cycle are recursive in the sense that conditions or limitations that arise in a given stage tend to carry over and have consequences for subsequent stages.

Beginning at the systems acquisition stage of the ITS life cycle, the experiences of the case study properties and recommendations of the Transit Standards Consortium (FTA 2005) suggest the following:

- Involve key stakeholders on systems procurement teams to ensure that the data produced by each system is compatible with that produced by other systems and that duplication among systems is minimized. Think ahead. A "stovepipe" approach to procurement can result in integration and interoperability problems as new systems are added. Stovepiping can be avoided by adopting a "data-centric" approach to procurement rather than an "application-centric" approach.
- Specify data integration and interface requirements in the procurement process.
- Be sure to have complete documentation for each system. It is important to know exactly how data are produced.
- Form an organizationwide data committee to ensure that the data recovered by ITS technologies are compatible with the needs of end users.

At the data management stage of the life cycle, lessons from the experiences of the case study properties include the following:

- The existence of standard industry templates for data models, applications, and data management would have spared agencies the need to re-invent the wheel in developing information systems for ITS data. Standardization is followed in other industries and results in more cost-effective and quicker implementation.
- Each agency should develop a comprehensive technology plan to document and prioritize technology strategies for the agency. The plan should cover all ITS technologies and include budget and staffing impacts. As an agencywide planning and budgeting tool, the technology plan would serve management by identifying and scheduling actions that must be taken through implementation.
- The business units responsible for maintaining data in the agency's database should monitor and ensure the validity and integrity of the data. As one person at a case study property observed, "Bad data can ruin trust." Post processing is a necessary step to ensure data integrity.
- Transit properties that are a part of city or county governments generally benefit from having access to city or county-level IT resources, but IT staff at these levels often lack familiarity with ITS data. Coordination with IT can also be more difficult.
- Invest in developing and maintaining meta-data and data dictionaries for the ITS databases. Researchers' credibility is at stake when they use ITS data, and they need to understand limitations of the data. Also, researchers can't tap the potential of ITS databases if they don't know the details of the data.
- Invest in training to support agencywide development of staff capabilities in using new enterprise applications for analyzing ITS data, such as GIS.

At the market research stage of the life cycle, lessons can be drawn from the experiences of the case study properties and literature addressing the strategic role of marketing and market research (Cronin and Hightower 2004, Fielding 1987, Stanley et al. 2003) and workforce development (TCRP 2001). These lessons include the following:

- The experiences of the case study properties and responses to the 2005 survey suggest that there is no "right" location of the market research function within the organization that optimizes the use of ITS data. At one case study property (CTA), market research resides within operations; at a second (TriMet), it is placed in the same division as IT; and at the third (Madison Metro), it exists as an independent entity. The *New Paradigms* approach, which emphasizes greater coordination between marketing and service development and delivery, would likely find advantages in the CTA alternative. The case studies also found synergistic spillover benefits from operations staff responsible for validating and maintaining ITS data from on-board systems to staff that analyze ITS data in monitoring and evaluating service delivery.

- Every property should prepare a marketing plan that identifies market research needs and establishes linkages to service development and operations plans. Ideally, marketing and operations plans would be coordinated, as envisioned by Fielding (1987). Apart from being a logical thing to do, such coordination would help to break down the traditional culture in the industry ". . . in which operational concerns have been viewed as of paramount strategic importance and customer concerns largely subordinated" (Stanley 2003: 3-14).
- Reports on service delivery performance produced by ITS vendor developed software should be viewed as a starting point in using ITS data for evaluating service delivery and leveraging market research. Staff at the case study properties have moved well beyond such reports, developing new performance indicators that are more closely aligned with customer satisfaction, defined through market research.
- Peer exchange (e.g., Gross et al. 2003) holds great potential for diffusing state-of-the-art practices at this juncture of the transit industry's ITS data transformation. Many of the innovative applications of ITS data that have been developed at the case study properties have not been communicated to the rest of the industry.
- Analysis of ITS data is currently limited to a few highly skilled persons who produce summary reports and do customized queries to address specific questions. They are somewhat concerned that the evolution toward wider access to ITS microdata could lead to misuse or misinterpretation and believe that general access should be limited to summary data.
- Apart from the difficulties of filling vacated positions, turnover of ITS data analysts interrupts the momentum of moving ITS data into research practice. At the case study properties, ITS data managers and analysts were investing considerable time building relationships with practitioners and decisionmakers to gain a better understanding of needs and opportunities.
- Traditional practices in market research, service planning, and scheduling are resistant to change. New tools and reports using ITS data to support practices and decisions in these areas need to be "sold." Reports or documents are not likely to be read. "Seminars" tend to be a more effective way of engaging staff, providing an opportunity for staff to suggest improvements.
- Transit properties commonly recognize the customer service benefits of ITS associated with trip planning software, automated stop announcements, real time vehicle arrival information, and using the AVL "playback" function to follow up on customer complaints. Surveys of riders and area populations have found that satisfaction and perceptions of service quality have been positively affected by these services.
- While there appears to be no practical limit to the number of service performance measures that can be derived from ITS data, this shouldn't be interpreted as a license to overwhelm managers with information. Information overload is more likely to occur in the age of ITS data and is a symptom of inadequate communication between analysts and managers.
- Market research departments commonly have few staff (the median full-time equivalent [FTE] in the 2005 survey was three) and survey projects are usually contracted out. Some of the leveraging opportunities involving ITS data are in supporting logistical aspects of survey research activity. Bringing contractors "up to speed" in understanding how to use the agency's store of ITS information is an issue that market research staff will need to address.
- One consequence of the ITS data transformation is that the skills needed among new hires are those that the industry is now having greatest difficulty recruiting and retaining (TCRP 2001). One strategy for getting ahead of the curve on this acute problem is to take a more aggressive approach with internships. The next generation of market researchers already has a positive attitude toward the transit industry, thanks to perceptions of its social and sustainability benefits. The industry would be more successful capitalizing on these perceptions now rather than at the point where it has greater difficulty competing with other industries in the full-time job market. Also, internships that are institutionalized through formal agreements, as is the case at CTA, have greater prospects for sustained success. The gap in compensation between the transit industry and private alternatives for persons in the marketing field, nevertheless, represents a serious barrier to hiring and retaining persons with the skills to analyze ITS data. The compensation gap appears to be greater for properties that are part of city or county governments, where pay is dictated by governmentwide pay scales (TCRP 2001).
- Related to internships, the transit industry should not assume that the curricula of the disciplines that are educating the next generation of market researchers are evolving to develop the skills that will be needed. The four largest "suppliers" of graduates to marketing programs in the transit industry—Marketing, Planning, Business, and Journalism (Cronin and Hightower 2004)—generally do not have a tradition of developing the skills that were demonstrated by staff that were the most active users of ITS data at the case study properties. Interns serve as a bridge between the transit workplace and education programs, and internship programs provide a mechanism for students and the transit industry to communicate their skill needs to education programs.
- Another avenue for supporting workforce development and the development of new practices using ITS data is

represented in the University Transportation Centers (UTC) program, administered by the Research and Innovative Technology Administration of the U.S. DOT. Many of the current 68 UTCs (located at 64 universities) have research and technology transfer themes that include ITS and transit. Projects that jointly engage market research staff and university faculty can produce cumulative benefits over time: (1) research can focus on developing new tools for analyzing ITS data, (2) UTC matching helps to leverage market research program resources, (3) involvement of graduate assistants helps to direct student interest toward careers in the transit industry, and (4) technology transfer activity can include training market research staff in ITS data applications. The experiences of two of the case study properties (CTA and TriMet) with UTCs indicate that the transit-university relationship has benefited both entities, especially when it is sustained over time and the partners are able to gain a better understanding of each other's respective needs and expectations.

At the fourth stage of the life cycle, the value of ITS data in market research is realized when the products of market research are used to inform management decisions. The "success stories" of the case study properties, in which ITS data are used to leverage or reinforce traditional market research practices, showcase outcomes that correspond very well to characteristics of effective market research programs presented in *TCRP Report 37*, "Integrating Market Research into Transit Management" (Elmore-Yalch 1998b).

One sign of an effective market research program identified in *TCRP Report 37* is its ability to move the organization beyond stated commitments to being customer-oriented to coordinating practices across departments that demonstrate an ability to follow through. The coordination of market research and operations functions may be most important in this context because operations is responsible for developing and delivering the "product" to transit riders. Here, market research provides direction to analysts who are developing and monitoring service using ITS data. At TriMet, for example, customer satisfaction surveys were the catalyst that served to focus the attention of operations analysts on the root causes of unreliable service. In this instance, reliability problems were traced to late departures from garages and terminals, and managers were able to clearly see a connection between improving departure times and improving customer satisfaction. Operations managers at the CTA were similarly motivated when a connection was found between rider satisfaction surveys and the incidence of "bus bunching" (documented through ITS data analysis). In this case, a "customer wait index" was developed from ITS data that allowed managers to track whether operations control practices were working from the customer's perspective. A similar story can be told about market segmentation studies, where the identification of latent demand through market research informs service planning.

A second sign of an effective research program is its ability to reduce the uncertainty that a manager faces in making decisions. Even the best designed, executed, and presented market research studies can only reduce uncertainty, not eliminate it. From a manager's perspective, the power of the information contained in a market research study is enhanced when that information is augmented or reinforced by information from other sources. Thus, when information from customer satisfaction surveys is coordinated with ITS information on service delivery, the power of the survey information is enhanced. It is something of a paradox that, at a time when transit data have never been more plentiful, managerial decisions often continue to be made on the basis of judgment and experience. Leveraging traditional market research information with ITS information will help to build the trust and confidence that managers need to make decisions based on research rather than judgment.

A third sign of an effective market research program is its ability to provide assessment information to a manager after a decision is made. Managers need to know whether the consequences of their decisions play out as expected or play out in other ways. When monitoring and evaluation become sustained practices, managers will "learn" from their decisions and, with accumulated knowledge, will make subsequent decisions with greater confidence and trust. The traditional approach to evaluation has been to conduct "before and after" studies. When market research studies are coordinated with service delivery monitoring drawing on ITS data, follow-up evaluation can begin immediately and run continuously until the next market research study.

Using ITS data to monitor service delivery should be considered a supplement rather than a substitute for traditional market research. In a few instances, however, ITS data may provide more reliable information to support decisionmaking. An example is Madison Metro's use of magnetic stripe card data to document pass program patronage, which informs the agency's negotiation of pass program agreements with local institutions. The traditional alternative, where agreements would rely on information from self-report surveys of transit use, would be subject to unknown levels of self-selection and reporting bias.

Looking across the four stages of the technology life cycle the most apparent overall lesson learned is that success in using ITS data for market research depends on agencywide coordination and communication. It is a rare instance where the responsibility for system deployment, data management, service delivery monitoring, and market research is confined to one division in an agency. Ensuring that all stages of the technology life cycle are coordinated is thus an executive management responsibility. Shouldering this responsibility may place some executives in unfamiliar territory, especially at smaller properties, and the situation is further complicated by the insularity that often exists among agency divisions.

Preparing a comprehensive technology plan provides a means of coordinating activities that are distributed across the agency. The most effective plans will look beyond capital and hardware issues to include resources needed to support changes in the data management infrastructure, as well as staffing and training needs in the end use departments. A comprehensive planning process will also force insular interests to coordinate their approaches to system implementation, which helps to ensure that ITS data will be successfully recovered, validated, stored, and analyzed.

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APPENDIX A

Chicago Transit Authority Case Study

The CTA is the nation's second largest transit property, serving 1.5 million weekday passengers with a fleet of 2,220 buses and 1,190 rail cars. Preliminary analysis pointed to the following reasons for selecting the CTA as a case study for this Guidebook:

- The CTA maintains a comprehensive market research program that is increasingly drawing on ITS data to monitor service delivery and to leverage traditional customer research practices.
- The CTA is an industry leader in analyzing customer data from smart cards and magnetic stripe cards in support of market research and planning.
- Although the CTA's experience with AVL and APC technology has been fairly brief (less than 3 years), it has developed an innovative array of intranet applications for monitoring service delivery and improving market research and planning.

The research team met with CTA staff in March 2007.

Organizational Structure

CTA's market research function resides within the Planning section of the Transit Operations division (see Figure A-1). The Planning section includes Strategic Planning (which houses market research), Service Planning, Scheduling, Facilities and Traffic Engineering, and Data Services. The creation of the Data Services unit within the Planning section was a consequence of the deployment of EFP, AVL and APC technologies, reflecting the interest of Planning section units in accessing and analyzing data for their purposes. Previously, for example, EFP data served the Finance section, and Planning units had to cross divisions and multiple sections to gain access to data.

Until recently, Data Services staff have been responsible for post-processing and merging data from the various systems, as well as developing applications for data analysis. The systems have been producing very large data volumes (3.2 million data records per day from the AVL and APC systems alone). A reorganization has shifted several staff to the IT section within the Management and Performance division to take responsibility for database management, while several analysts remained within Data Services.

Experience With Smart Cards and Magnetic Stripe Cards

Smart cards were introduced in 2002 and are offered in two versions. The Chicago Card (CC) is a stored value device with optional registration. Card balances can be recharged at ticket vending machines. The Chicago Card Plus (CCP) is managed through a Web-based account that is recharged by credit card. All CCPs are registered to users. Registration information includes a billing address, an optional email address, and an optional field for customers to opt in for market research studies. The number of customers responding positively to the market research option has been limited. No demographic information is collected in the registration process. The demographics of smart and magnetic stripe card users are recovered from customer satisfaction surveys. The most recent count of CC and CCP cards in circulation is 530,000, of which 250,000 are registered with email addresses.

Magnetic stripe cards were introduced in 1997. Following their introduction all flash passes and tokens were eliminated. There are a number of alternative purchase options. Single ride cards are sold in packs of 10 and 20. Unlimited ride passes are offered for 1, 7, and 30 day's duration, as are unlimited ride "visitor" passes covering 1 to 5 days. The unlimited ride cards are activated on first use. Lastly, cards are sold in stored value amounts ranging from $2.25 to $20.00 (rechargeable through ticket vending machines). Transactions on the CTA rail system are limited to cards, while cash remains a payment option on the bus system.

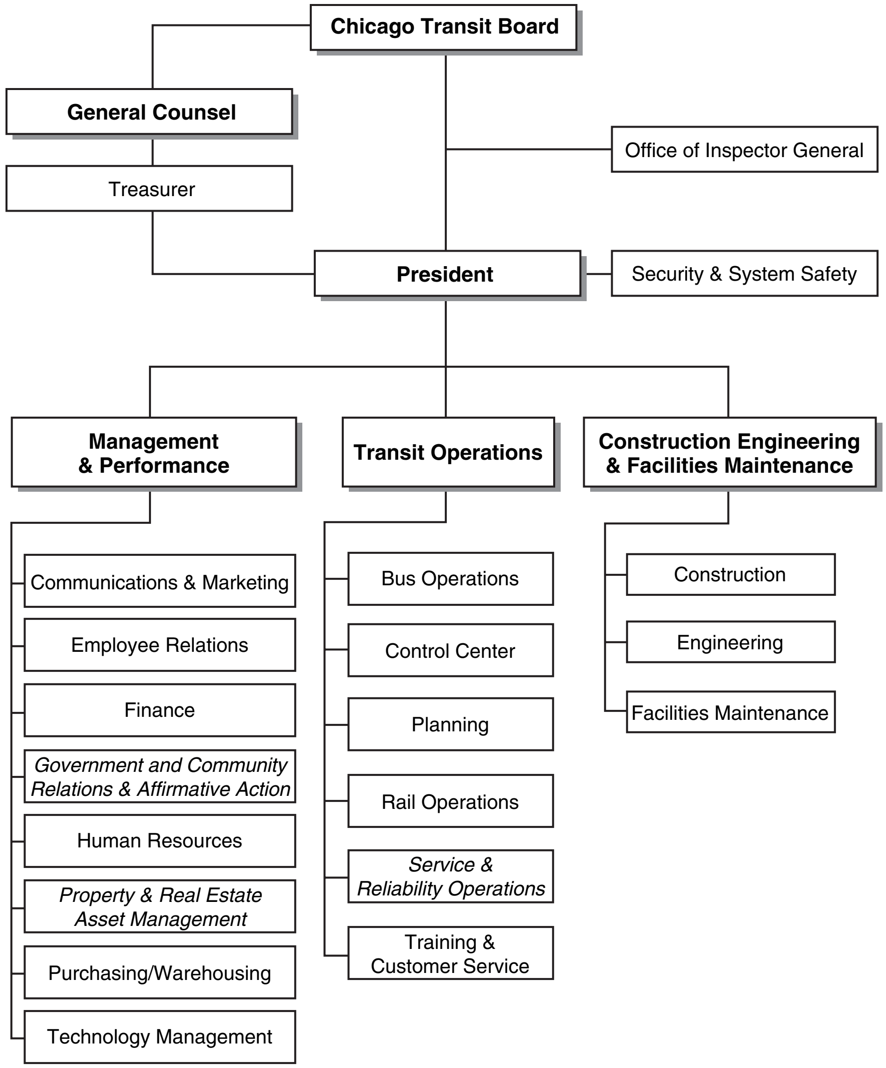

Figure A-1. CTA organizational structure.

About 50% of the trips on the CTA system involve a transfer. In January 2006, free transfers were eliminated for cash fare riders, and the share of cash transactions subsequently fell from about 30% to under 10%. In mid-2006, stored value MS cards accounted for the largest share of transactions (about 25%), followed by 7-day MS cards (about 22%). CC and CCP transactions accounted for about 18%. Over time, transactions have become much more differentiated among fare media. In January 1999, before the introduction of smart cards, cash and stored value MS cards accounted for nearly 80% of transactions. By July 2006, they accounted for just over 30%. The increasing differentiation in fare media has been reinforced by focus group and survey analysis showing very strong customer preferences for the fare payment options they select.

Increasing diversity of fare payment options, coupled with the pricing flexibility inherently available with card technology, has led to greater interest in exploring the revenue and ridership impacts of alternative pricing schemes. The CTA's fare change model, first developed in the 1970s, has been updated to accommodate the evolution of fare payment options (Multisystems and NuStats International 2000). The fare change model is structured around passengers' fare media choices through stated preference exercises. Derived demand elasticities, in turn, are applied in estimating revenue and ridership. Calibration of the model has been periodically updated through stated preference surveys, and fare change model estimates can now be evaluated against the actual behavior of customers represented in fare media usage data. The fare change model was put to the test in assessing a recent substantial fare increase. It predicted a large growth in revenue with limited impacts on ridership, which was subsequently borne out.

Fare card transactions are recorded at the entry station on the rail system. CTA analysts have been able to infer exit locations from the sequence of card transactions that occur

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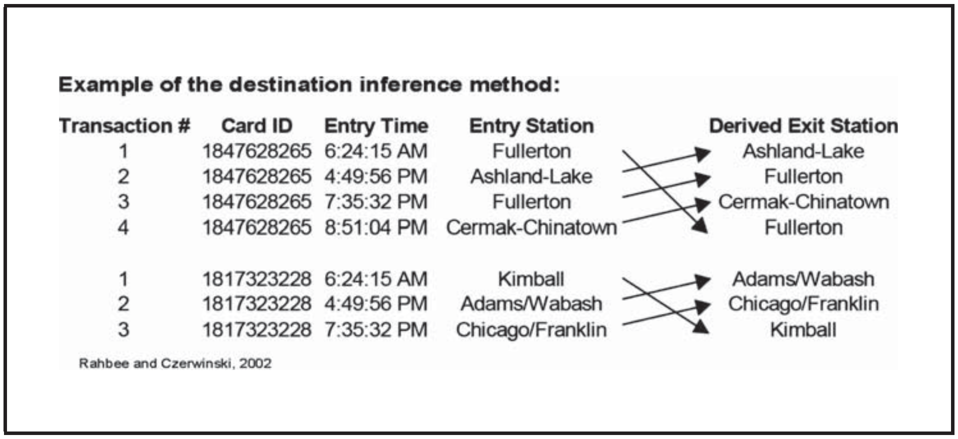

Example of the destination inference method:

Transaction #	Card ID	Entry Time	Entry Station	Derived Exit Station
1	1847628265	6:24:15 AM	Fullerton	Ashland-Lake
2	1847628265	4:49:56 PM	Ashland-Lake	Fullerton
3	1847628265	7:35:32 PM	Fullerton	Cermak-Chinatown
4	1847628265	8:51:04 PM	Cermak-Chinatown	Fullerton
1	1817323228	6:24:15 AM	Kimball	Adams/Wabash
2	1817323228	4:49:56 PM	Adams/Wabash	Chicago/Franklin
3	1817323228	7:35:32 PM	Chicago/Franklin	Kimball

Rahbee and Czerwinski, 2002

Figure A-2. Derived CTA exit locations from entry location sequence data.

over the course of a given day (see Figure A-2). This approach assumes that passengers return to the destination station of their previous trips and that at the end of the day they exit the same station they first entered. Using this approach, Rahbee and Czerwinski (2002) were able to successfully infer 70% of passengers' destinations from sequential station entry data. Using scaling factors to account for station-specific variations in unsuccessful entry-exit matches, they estimated an origin-destination trip table for the rail system.

For many rail origin-destination pairs the route path is determinant. Passengers boarding at stations in the Loop, however, have directional options. Given that most Loop stations serve either direction, path choice cannot be directly determined from card transaction data. A few Loop stations are direction-specific, allowing analysis of path choice. Selection of the shortest path may minimize travel time, but transactions data from directional stations indicates that some passengers opt for a lengthier alternative path possibly because the choice improves their likelihood of finding an available seat. Analysis of the travel time differences involved in such choices, along with passenger surveys, can yield estimates of the implicit monetary value that customers place on improvements in comfort and convenience associated their trip making (Zhao 2004).

On the bus system, card transaction data include the time of transaction, the vehicle's farebox ID, and the route ID. The location of the transaction is not directly identified. However, by joining the card and AVL data streams, the stop associated with the transaction can be inferred from the location status of the bus at the time of the transaction (Cui 2006).

CCP card holders' station or stop accessibility can be analyzed by relating billing addresses to entry station transactions or inferred stop transactions using a GIS (see Figure A-3). Analysis of CCP station transaction data found that 40% of card holders "resided" more than two miles from their entry station, indicating that billing and residential addresses may differ or that other (non-walk) travel modes may be used to access stations.

The CTA has used CCP card data in preparing for major reconstruction along the Brown Line north of the Loop, which is among the system's most heavily-traveled corridors. Information on station closures is being targeted to riders whose transaction information shows them to be users of the affected stations (see Figure A-4). GIS has also been used to create a buffer along the Brown Line corridor to examine census data on languages spoken in the home, so that information on construction and travel options can be more effectively communicated.

Travel disruptions from reconstruction along the Brown Line may be mitigated by the fact that many CTA customers have the option of traveling on bus routes that also serve the corridor. Analysis of CCP data revealed a pattern of rail and bus preferences in the corridor (see Figure A-5). Estimates of expected changes in rail preference related to the Brown Line reconstruction should prove helpful in planning for additional bus service, as well as in targeting information to customers on travel options that will be available during the project.

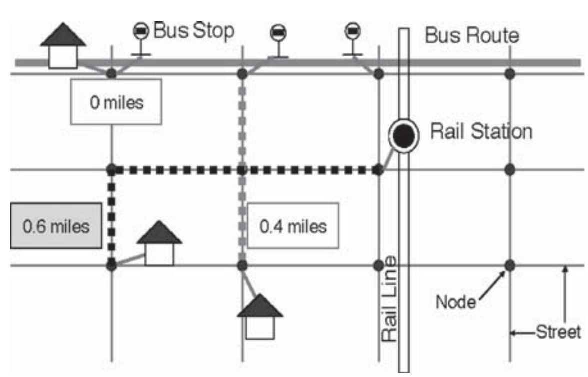

Figure A-3. Station accessibility.

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Brown Line Station Preference, Chicago Card Plus Customers

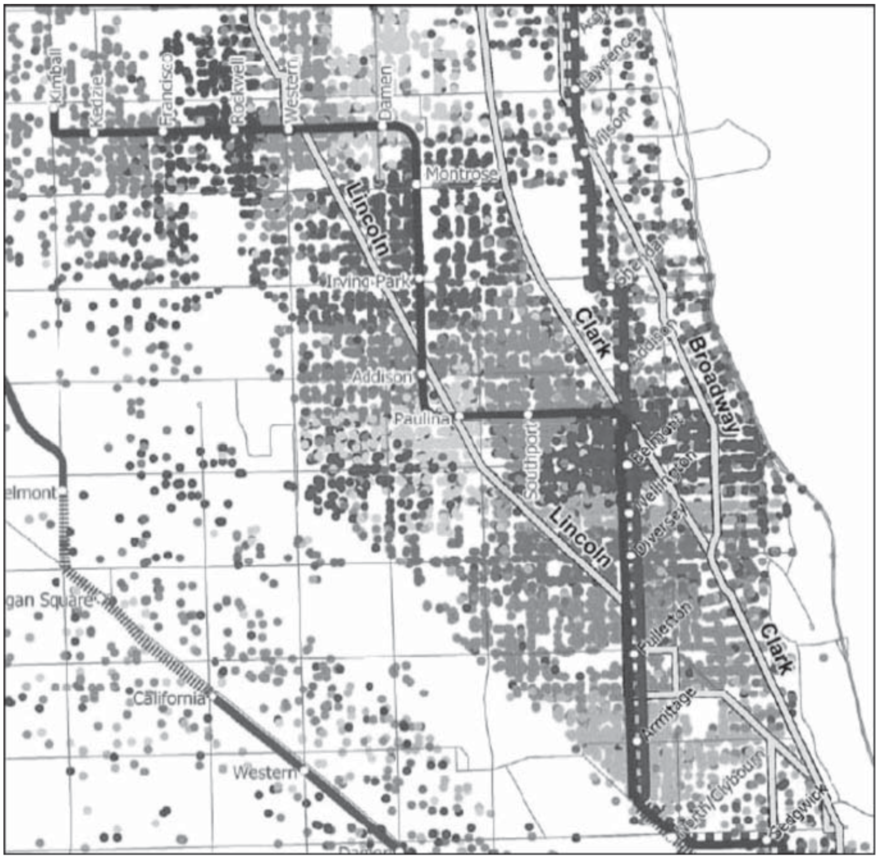

Figure A-4. Station usage of Chicago Card Plus holders along the CTA Brown Line.

CTA's Experience With AVL and APC Technology

AVL and APC technologies are integrated in the CTA's automated voice annunciation system (AVAS), which was deployed on the bus fleet in 2002 following a court order related to the Americans with Disabilities Act. All buses in the fleet are AVL-equipped, and about 45% (35% of standard buses and 100% of articulated buses) of buses have APC units. APC units are being specified in all new bus acquisitions, with a goal of 100% coverage by 2013.

The general organization of ITS data flows in AVAS is illustrated in Figure A-6. Data that are uploaded to buses from the BusTools workstation include data from the HASTUS Scheduling System and timepoint/stop location coordinates. These data allow assignment of APC passenger movement data to unique locations (stops), and also allow AVL actual time-at-location data to be related to the corresponding scheduled time-at-location data, facilitating analysis of schedule and headway adherence. The recovered AVL and APC data are downloaded once daily through a wireless link to a server located at each garage, and then forwarded for post-processing. Data archiving is managed in an Oracle database and processed twice daily. Archived data can be accessed from desktop workstations through an intranet web server, where reporting and analysis tools reside.

AVAS summary reports and analysis tools available on CTA's intranet web server are shown in Figure A-7. Summary reports of passenger movements from APC data are generated by Ridecheck Plus reporting software. The structure of the summary reports differentiates by route, time period and direction. Load and maximum load reports can also be generated for selected routes and locations. AVL data are processed to report vehicle running time information with respect to schedule adherence and on-time performance from the stop to the system level for selected time periods. Reports on the operating status of AVAS equipment and the screening of data recovered are also available for maintenance personnel.

Consistent and dependable service is highly valued by transit customers (Morpace International and Cambridge Systematics 1999). From a service delivery perspective, consistency and dependability cannot be delivered when schedules are incompatible with actual operating conditions. The

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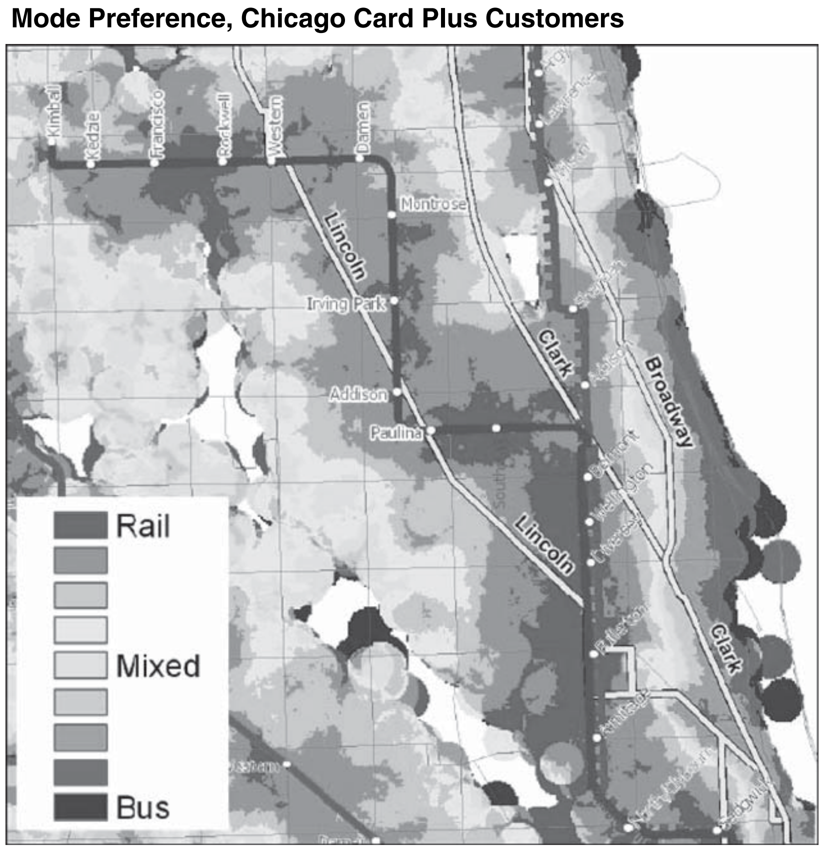

Figure A-5. CTA rail and bus mode preferences.

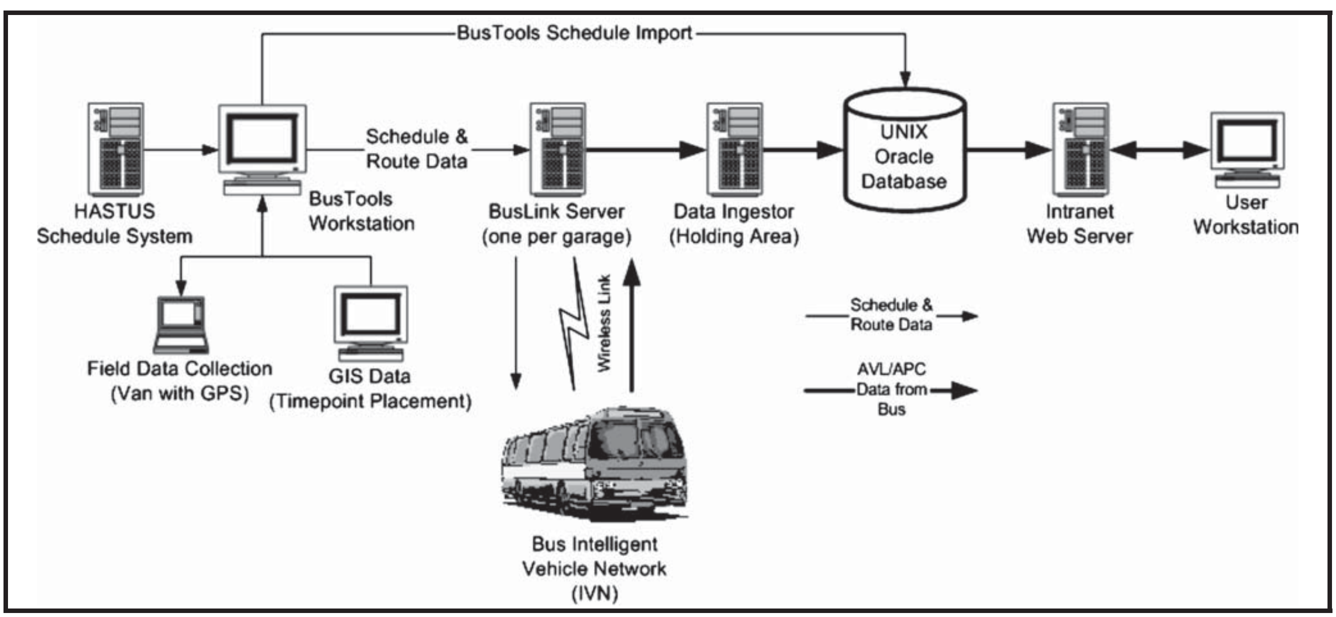

Figure A-6. Data flows in AVAS.

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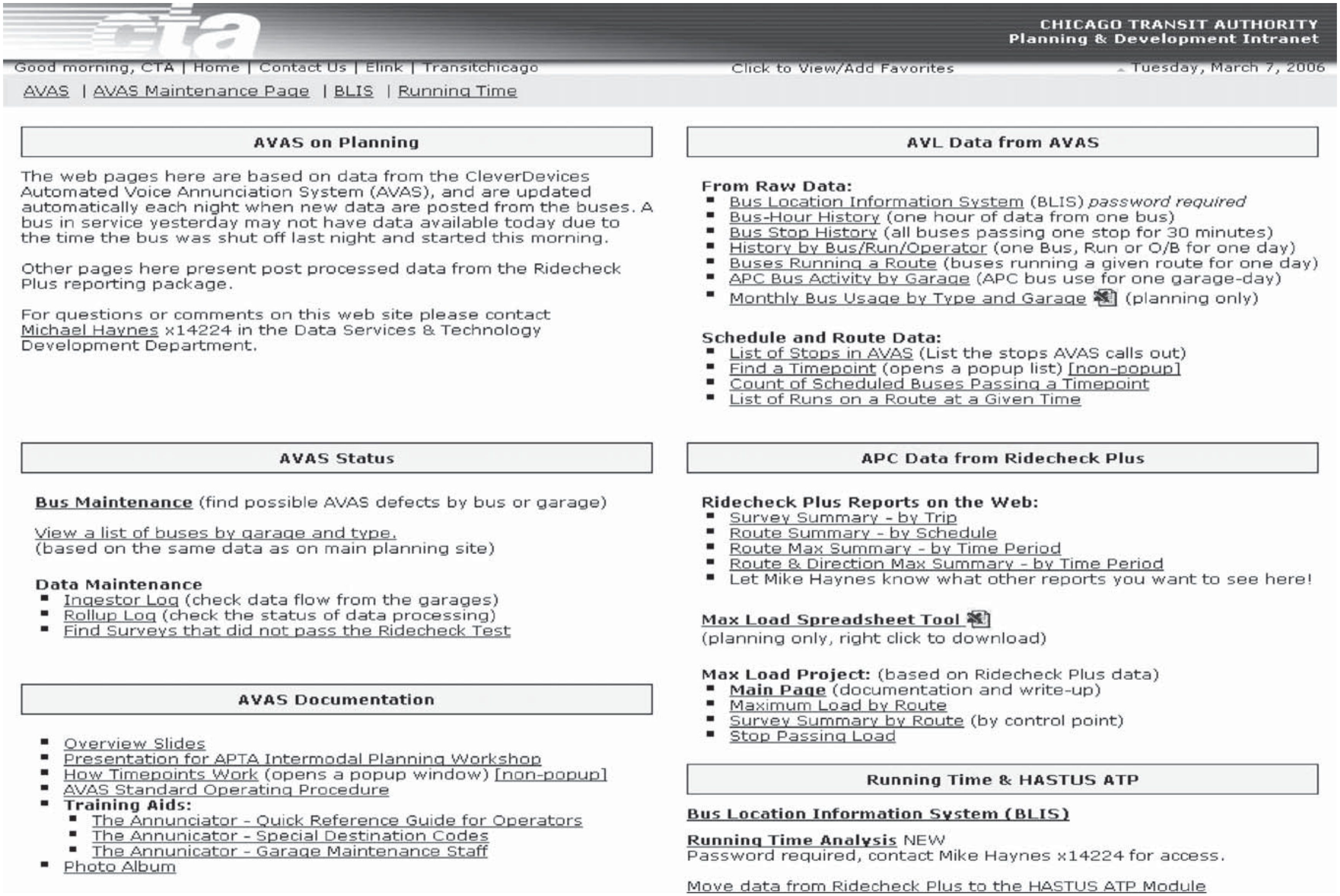
CHICAGO TRANSIT AUTHORITY
Planning & Development Intranet

Good morning, CTA | Home | Contact Us | Elink | Transitchicago   Click to View/Add Favorites   Tuesday, March 7, 2006

AVAS | AVAS Maintenance Page | BLIS | Running Time

AVAS on Planning

The web pages here are based on data from the CleverDevices Automated Voice Annunciation System (AVAS), and are updated automatically each night when new data are posted from the buses. A bus in service yesterday may not have data available today due to the time the bus was shut off last night and started this morning.

Other pages here present post processed data from the Ridecheck Plus reporting package.

For questions or comments on this web site please contact Michael Haynes x14224 in the Data Services & Technology Development Department.

AVAS Status

Bus Maintenance (find possible AVAS defects by bus or garage)

View a list of buses by garage and type.
(based on the same data as on main planning site)

Data Maintenance
- Ingestor Log (check data flow from the garages)
- Rollup Log (check the status of data processing)
- Find Surveys that did not pass the Ridecheck Test

AVAS Documentation

- Overview Slides
- Presentation for APTA Intermodal Planning Workshop
- How Timepoints Work (opens a popup window) [non-popup]
- AVAS Standard Operating Procedure
- **Training Aids:**
  - The Annunciator - Quick Reference Guide for Operators
  - The Annunciator - Special Destination Codes
  - The Annunciator - Garage Maintenance Staff
- Photo Album

AVL Data from AVAS

From Raw Data:
- Bus Location Information System (BLIS) *password required*
- Bus-Hour History (one hour of data from one bus)
- Bus Stop History (all buses passing one stop for 30 minutes)
- History by Bus/Run/Operator (one Bus, Run or O/B for one day)
- Buses Running a Route (buses running a given route for one day)
- APC Bus Activity by Garage (APC bus use for one garage-day)
- Monthly Bus Usage by Type and Garage (planning only)

Schedule and Route Data:
- List of Stops in AVAS (List the stops AVAS calls out)
- Find a Timepoint (opens a popup list) [non-popup]
- Count of Scheduled Buses Passing a Timepoint
- List of Runs on a Route at a Given Time

APC Data from Ridecheck Plus

Ridecheck Plus Reports on the Web:
- Survey Summary - by Trip
- Route Summary - by Schedule
- Route Max Summary - by Time Period
- Route & Direction Max Summary - by Time Period
- Let Mike Haynes know what other reports you want to see here!

Max Load Spreadsheet Tool
(planning only, right click to download)

Max Load Project: (based on Ridecheck Plus data)
- **Main Page** (documentation and write-up)
- Maximum Load by Route
- Survey Summary by Route (by control point)
- Stop Passing Load

Running Time & HASTUS ATP

Bus Location Information System (BLIS)

Running Time Analysis NEW
Password required, contact Mike Haynes x14224 for access.

Move data from Ridecheck Plus to the HASTUS ATP Module

Figure A-7. AVAS intranet reporting and analysis tools.

development of schedules that provide consistent and dependable service relies on detailed knowledge of the pattern of vehicle running times on a route. The AVAS recovers a large volume of running time data that can be used to inform the HASTUS scheduling system. A new analysis tool on the intranet web site facilitates analysis of running time patterns for routes and route segments. The tool provides plots of actual running times in relation to scheduled running times for visual examination. A related tool provides estimates of optimal running and recovery times based on the observed patterns.

Figure A-8 illustrates the end-to-end pattern of actual running times in relation to scheduled running times for one of the CTA bus routes. Although the schedules provide greater running times during the morning and evening peak periods, it is apparent from the plot that the actual running times of buses serving the route are notably greater than the scheduled times, except during the 6:00-8:00 pm period. The variation in actual running times also appears to be much greater between 2:30 and 4:30 pm than at other times.

A related tool translates the pattern of observed running times into optimal scheduled running and recovery times (see Figure A-9). This calculation is based on the objective of providing running time that is sufficient to accommodate 65% of scheduled trips, and adding recovery time that is sufficient to accommodate 95% of trips serving a route. In the example shown in Figure A-9, the optimal and scheduled running times are fairly close for northbound trips during the Owl, Early AM, and AM Peak periods, while the scheduled running times substantially exceed optimal running times during the Midday and PM Late periods.

Although available systemwide, the running time tool has not yet been applied to all routes due to time demands on scheduling staff. There is an expectation that a systemwide evaluation would identify more instances where running time could be reduced than where additional running time would be needed. This expectation reflects traditional scheduling practices that respond to operator and customer feedback that tends to focus on circumstances where running time is inadequate, while being less attuned to circumstances where running time is excessive. If so, there would be an opportunity to improve both schedule reliability and schedule efficiency.

Reconsidering Performance Measures

As the CTA board and senior management have become more familiar with applications of ITS data in the Transit Operations division, they have begun to encourage development of new performance measures. The system level performance metrics that have been tracked over time by CTA include ridership, on-time performance (bus), delay (rail), vehicle and station cleanliness, safety, customer complaints/commendations, and affordability.

Surveys indicate that reliable service is a high priority among customers. While on-time performance is a reliability indicator, it is more relevant in lower frequency service environments,

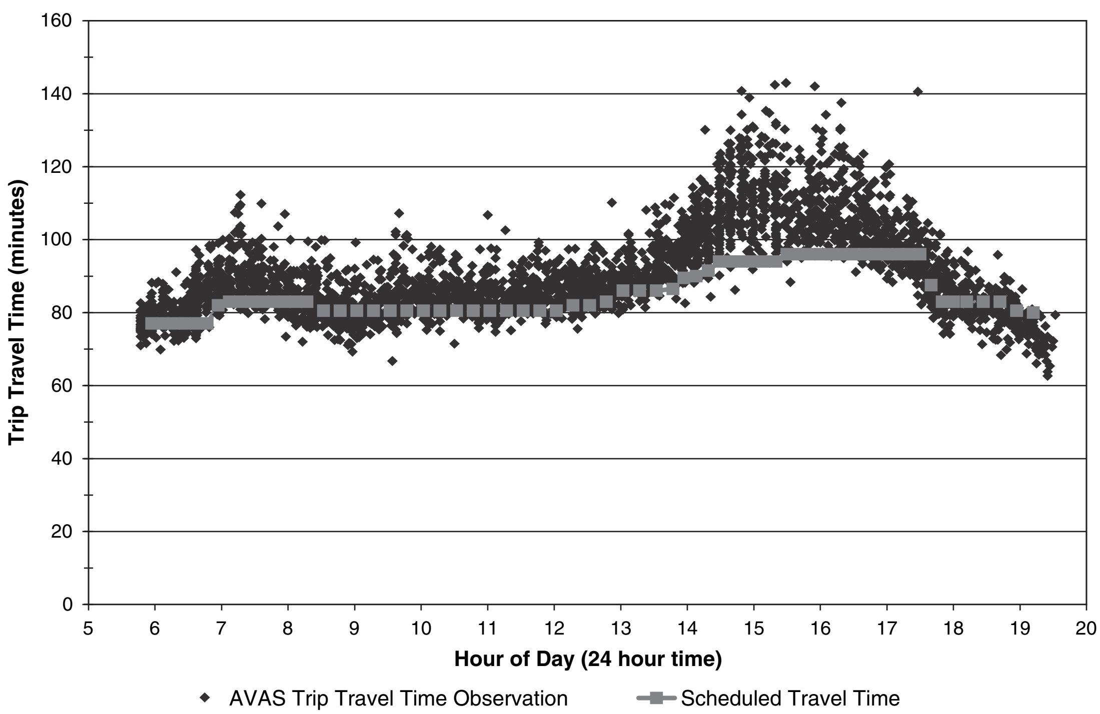

Figure A-8. Actual versus scheduled running times.

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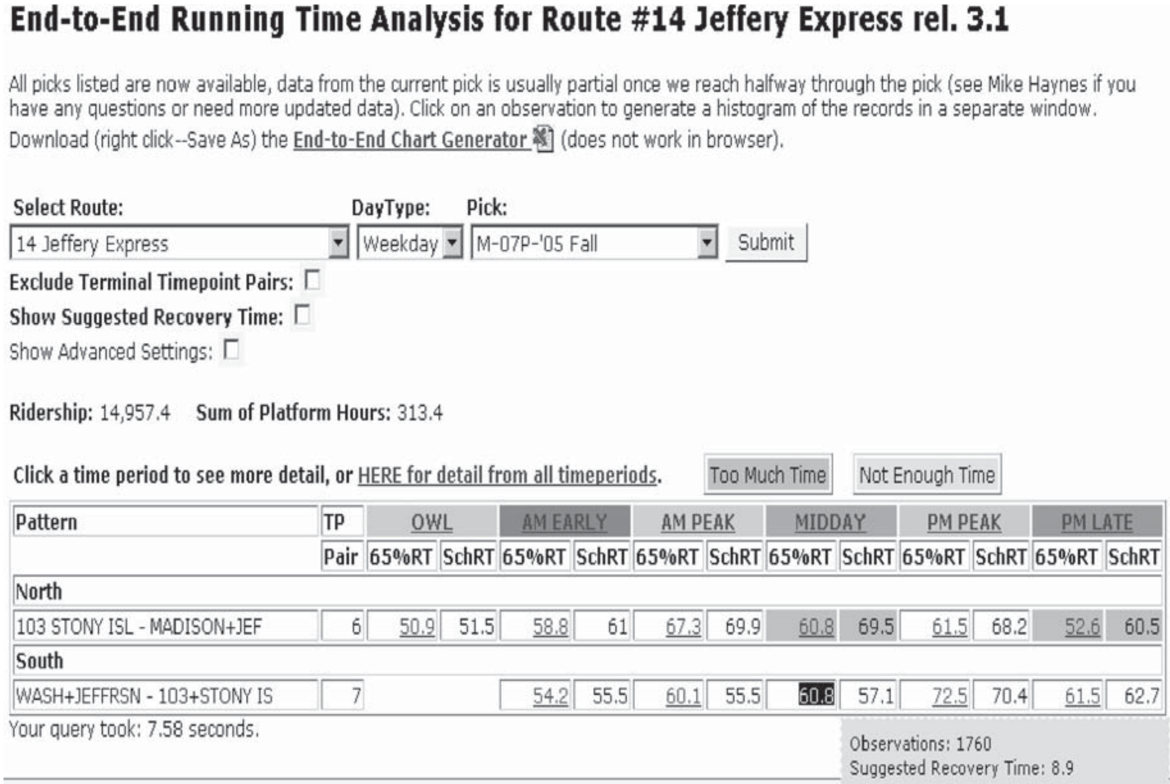

End-to-End Running Time Analysis for Route #14 Jeffery Express rel. 3.1

All picks listed are now available, data from the current pick is usually partial once we reach halfway through the pick (see Mike Haynes if you have any questions or need more updated data). Click on an observation to generate a histogram of the records in a separate window.
Download (right click--Save As) the End-to-End Chart Generator (does not work in browser).

Select Route: 14 Jeffery Express | DayType: Weekday | Pick: M-07P-'05 Fall | Submit
Exclude Terminal Timepoint Pairs:
Show Suggested Recovery Time:
Show Advanced Settings:

Ridership: 14,957.4 **Sum of Platform Hours:** 313.4

Click a time period to see more detail, or HERE for detail from all timeperiods. | Too Much Time | Not Enough Time

Pattern	TP	OWL		AM EARLY		AM PEAK		MIDDAY		PM PEAK		PM LATE	
	Pair	65%RT	SchRT	65%RT	SchRT	65%RT	SchRT	65%RT	SchRT	65%RT	SchRT	65%RT	SchRT
North													
103 STONY ISL - MADISON+JEF	6	50.9	51.5	58.8	61	67.3	69.9	60.8	69.5	61.5	68.2	52.6	60.5
South													
WASH+JEFFRSN - 103+STONY IS	7			54.2	55.5	60.1	55.5	60.8	57.1	72.5	70.4	61.5	62.7

Your query took: 7.58 seconds.
Observations: 1760
Suggested Recovery Time: 8.9

Figure A-9. Optimal versus scheduled running time.

where customers plan their travel to coordinate with schedules. In high frequency service environments, customers tend to disregard schedules and pay more attention to the consistency of service. Nearly 90% of CTA customers access the transit system when headways are 12 minutes or less, suggesting that an indicator based on headway consistency would serve as a better indicator of reliability than one based on schedule adherence.

One headway-based reliability indicator under consideration at CTA is related to the wait assessment measure developed by New York City Transit (NYCT). This indicator measures the percentage of customers whose actual wait is less than the scheduled headway plus three minutes (during peak periods) or five minutes (during off-peak periods). Unlike the NYCT measure, which relies on manually collected data from selected high-volume locations, the CTA wait assessment measure can be calculated systemwide from archived AVL data. A prototype of CTA's wait assessment indicator is presented in Figure A-10.

A related headway consistency indicator developed at CTA relates to "bus bunching," which occurs when the actual headway separating buses becomes very small. Bunching is a source of irritation to customers, who usually face longer waits only to find the lead bus of a bunched pair overloaded. It is also a waste of effective capacity for the service provider, because the trailing bus usually carries a much smaller passenger load. AVL data can be used to document the incidence of bus bunching, as shown in Figure A-11. In this example, the incidence of bunching is clearly greater during peak periods, when passenger volumes are larger and traffic congestion poses the greatest challenge to maintaining consistent transit operations.

Other ITS-Related Market Research Activities

The CTA is planning to execute an on-board O-D survey in spring 2007. This will be the first systemwide O-D survey undertaken since the 1970s. Fare card and APC data will be used in designing the sampling plan for the survey and will provide the expansion factors for the survey results. The distribution of the surveys will also include an advanced technology feature. Surveyors will use special pens that will record the serial number of each survey and will be linked to bus AVL data via a time stamp, permitting geocoding of the location where it is distributed.

The 2007 O-D survey will provide the first comprehensive basis for validating the rail and bus system trip tables that had been previously developed from fare card transactions and APC data. Of particular interest to CTA staff is the validation of path choices in the rail system and transfers within the bus system. While O-D surveys traditionally provide only a snapshot of activity in a transit system at given point in time, the

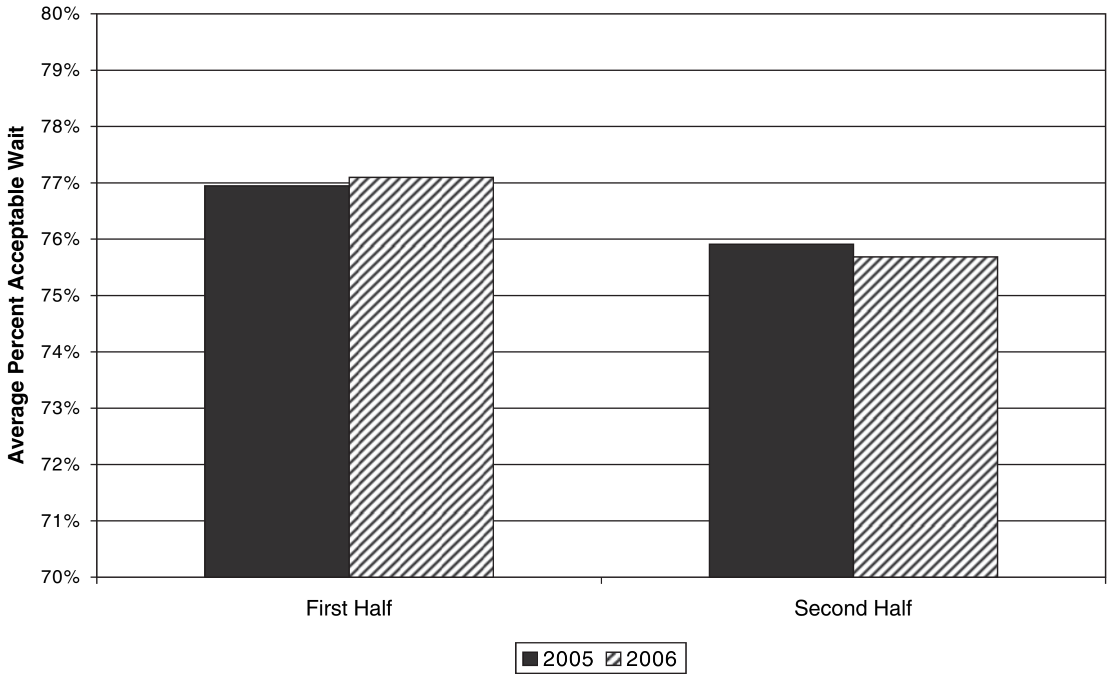

Figure A-10. Wait assessment indicator for CTA bus service.

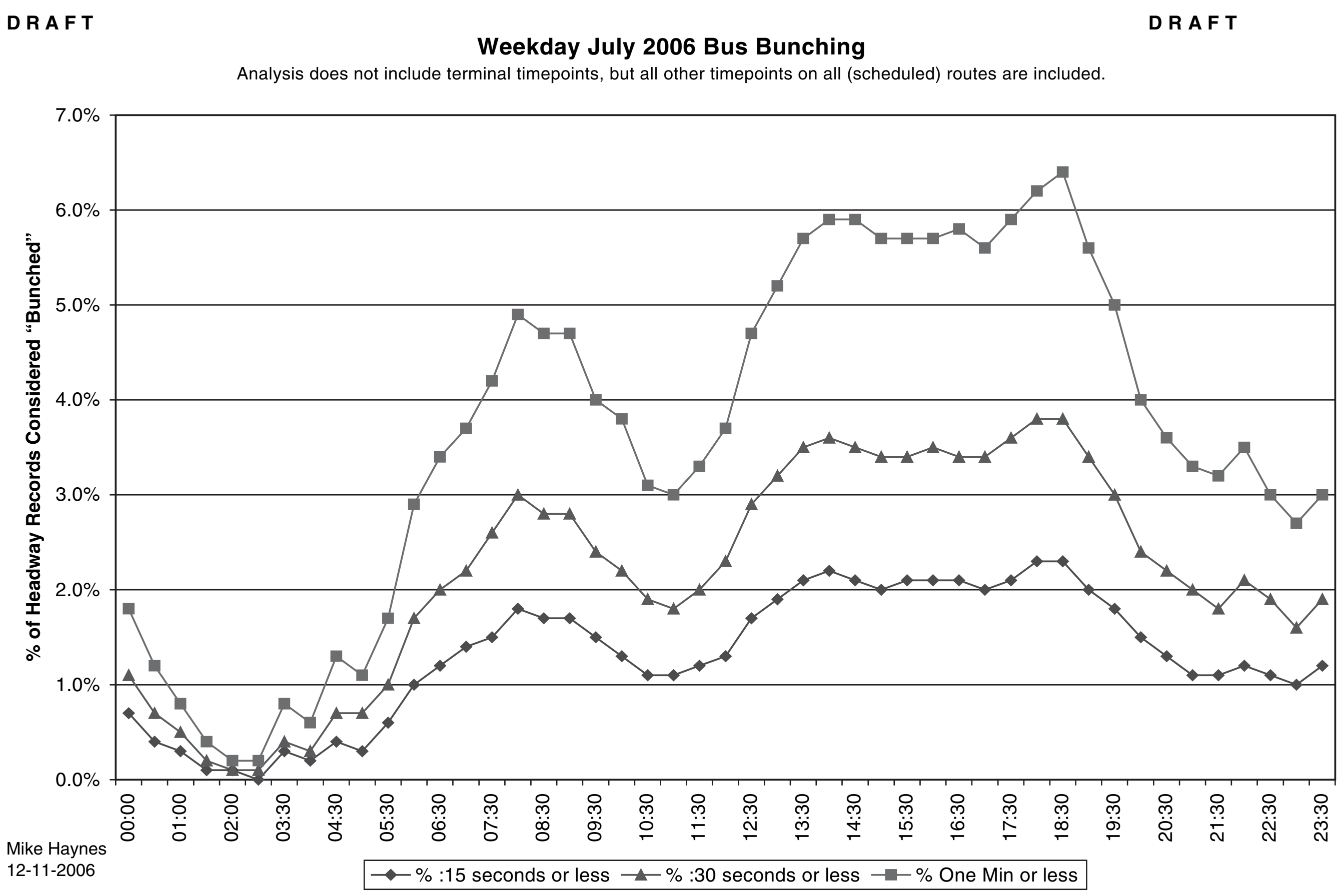

Figure A-11. Incidence of bus bunching by time of day.

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2007 survey is viewed by CTA staff as providing a "ground truth" starting point that will be regularly updated through time using current transaction and passenger movement data.

In another market research application, CTA staff used AVL and APC data to evaluate the effects of providing real time arrival information (on the Internet and at one bus shelter) on the #20 Madison bus route. APC data were used to select the shelter where arrival information would be provided and a second shelter with similar passenger volumes, which served as a control. Riders were surveyed on perceptions of wait times before and after implementation of posted arrival time service. Surveyed riders at the control stop perceived no change, while those surveyed at the stop where arrival times were posted perceived a 27% improvement in wait times. The corresponding AVL data indicated that the control stop riders were "right": wait times did not change. Similar findings have been obtained in London (Nelson 1995, Schweiger 2003), suggesting that wait time uncertainty rather than actual wait time is what customers find more onerous, especially when service is fairly frequent, and that the main benefit from posting arrival times is in reducing uncertainty.

Evaluation of fare card transactions data has provided insights on travel activity related to special events and user groups. Convention passes were tested at events such as the Gay Games and the Rail~Volution conference. Data from UPasses (issued to college students) are used in revenue estimation, building new markets and planning for service disruptions. Student travel also differs seasonally and by time of day, and having card transactions data helps in planning service. Surveys also found that college student riders were perceived by others to enhance safety (especially at night) and that they tended to have a calming influence on high school riders.

The CTA is currently in the process of validating its APC data against data on actual passenger movements from onboard cameras. This is the first step in transitioning to a new sampling plan using automated data for NTD reporting.

Alternatives evaluation in connection with development of the Pink Line rail project was cited by staff as an example of the "new approach" to using ITS data for market research at the CTA. The Pink Line was created by splitting off and realigning a trunk of the Blue Line. The alternatives analysis first drew on rider survey data to validate O-D flows inferred from card transaction data. A network model was then used to assign trips and estimate travel time savings associated with the alternatives. Further analysis examined impacts on negatively affected riders by origin and destination. The alternative selected was shown to produce an overall estimated 2.3% reduction in travel times relative to the previous alignment, with an improvement in travel time for 98% of affected riders.

Issues, Observations, and Challenges

There is an evident transformation underway in the market research and planning activities at CTA, wherein the use of ITS data is playing a more central role in the practices employed by staff. This was clearly demonstrated in the interviews conducted during our site visit, and in the subsequent review of materials and publications provided to us by CTA staff. When we queried staff on the transformation they emphasized that it has not been seamless and that many challenges (financial, technical, entrenched practices) remain. Nevertheless, it was generally acknowledged by those who we interviewed that they were involved in developing innovative applications of ITS data, and that they were "ahead of the curve" in relation to most other transit properties. Staff noted that the success that they have experienced is not a direct consequence of the size of their property, given that market research and planning staff numbers at CTA are roughly comparable to staff numbers at properties serving half their customer base. We asked "what specific things can you point to" that have made a difference in achieving more effective use of ITS data? This question drew the following responses.

First, the CTA has engaged in a formal arrangement with the transportation and planning programs at the Massachusetts Institute of Technology and the University of Illinois at Chicago to employ masters program students as interns. The interns spend two summers in residence at CTA, familiarizing themselves with practices and identifying a thesis problem during the first summer, and completing their thesis research during the second. The research undertaken by interns is viewed as the development of prototype applications of ITS data that can eventually evolve into adopted practices. The internship program has also served as a career pathway between the participating institutions and the CTA. Two of the six staff that we interviewed identified themselves as veterans of the internship program.

Second, the U.S. DOT/FTA-sponsored Peer-to-Peer Development Program was mentioned as a useful means of sharing experiences and practices related to the development of tools and applications that draw on ITS data. For the CTA, the exchange involved staff from TriMet (Portland) and King County Metro (Seattle). One reason the Peer-to-Peer Program was considered beneficial is that the development of new applications was evolving so rapidly that it was not being well documented in the professional literature (Gross et al. 2003).

Third, one of the challenges to effective use of ITS data is the gap separating development and use of new applications. This is being addressed at the CTA through a series of internal "what's new" brown bag seminars. The seminars have proved to be effective in disseminating information about new applications, and they allow market research and planning staff to communicate their needs to those involved in the development of the applications. The seminars also stimulate questions from users and encourage exploration of new uses for the data more effectively than can be achieved through providing system documentation (which many cannot find the time to read).

Fourth, staff turnover represents another challenge to developing and implementing new ITS data applications. There are a limited number of people in the transit industry who are both capable of working with ITS data archives and also have a deep understanding of market research, scheduling, and planning practices. When staff with these abilities leave they are not easily replaced, and the momentum of the working relationship between the analyst and practitioner is interrupted.

Finally, the creation of the Data Services unit within the planning section helped to bridge the gap between ITS database management and administration (which resides in the Management & Performance Division) and market research staff. Data applications involve complex queries and joining of data tables, skills that are beyond the capabilities that are typically found in market research and planning environments.

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CTA Staff Interviewed

Jeffrey Busby, Manager, Market Research
Alex Cui, Project Coordinator, Data Services
Elizabeth Donahue, GIS Analyst, Data Services
Mike Haynes, Project Manager, Transit Systems Support, Technology Management
Aimee Lee, Manager, Resource Planning
Kevin O'Malley, Manager Data Services
Jeffrey Schroeder, Manager, Transit Systems Support, Technology Management
Jeffrey Sriver, General Manager, Strategic Planning

APPENDIX B

City of Madison—Metro Transit Case Study

City of Madison-Metro Transit (Madison Metro) provides fixed route bus service to a metropolitan area of approximately 250,000 residents. The Madison Metro system comprises 56 routes (including four dedicated to the University of Wisconsin campus and one providing capitol area parking shuttle service). Its fleet of 202 buses carried over 12 million boarding riders in 2006. Transit use in the Madison region is quite high in comparison with other metropolitan areas of similar size. Census 2000 data show that over 12% of city residents commute by transit, a likely reflection of the presence of a major university enrolling over 41,000 students and a metropolitan economy in which more than 30% of the labor force is employed in the state and local government sectors.

Preliminary analysis pointed to the following reasons for selecting Madison Metro as a case study for this Guidebook:

- Madison Metro is a moderately sized agency that has deployed ITS technologies fairly recently. Deployment of AVL, APC, and magnetic stripe card systems occurred in 2004–2005. Prior to deployment there was little data collection or analysis.
- Madison Metro has developed a successful pass program involving the University of Wisconsin, local colleges, the City of Madison, and area hospitals. Data from magnetic stripe cards are used in pass program pricing and service planning.
- Madison Metro has drawn on non-transit ITS data in its market research activities.

The research team met with Madison Metro staff in March 2007.

Organizational Structure

Madison Metro's organizational structure is comparatively flat (see Figure B-1). Market research and service planning/scheduling are distinct functions on a par with finance and transit services (which includes operations, maintenance, and paratransit). Staff numbers are relatively limited. Planning and scheduling consists of six persons, while fourteen persons (including nine customer service representatives) make up the marketing and customer services unit. A two-person information systems unit is responsible for managing data across the agency.

Madison Metro is a department of the City of Madison, which has both advantages and disadvantages. On the plus side, it has been supported by the city's information services (IS) unit in integrating GIS data with transit ITS and market research data. Also, the agency is overseen by the city's Parking and Transit Commission, which has endorsed downtown parking pricing policies that are very transit supportive (e.g., monthly parking fees in the city's downtown garages are $133, compared with $47 for a monthly transit pass). On the negative side, Madison Metro is required to conform to the city's policies that may not be applicable, such as for Web design, and it receives little support from the city's IS department in maintaining its ITS databases.

Experience With AVL, APC, and Magnetic Stripe Cards

Madison Metro participated with other transit agencies in the state in a system procurement process coordinated by the Wisconsin DOT (WiDOT). Milwaukee Transit played a lead role in selecting ITS technologies, while the other transit agencies could opt in if they desired. Although Madison Metro's general manager has been in his current position for less than a year, he was directly involved in the WiDOT-coordinated ITS procurement process while serving as the GM for another of the participating transit agencies.

The ITS technologies selected by Madison Metro include AVL (with automated voice annunciation) and APCs, deployed in 2004, and magnetic stripe cards, deployed in 2005. APCs are installed on 38% of the fleet. All of the systems are

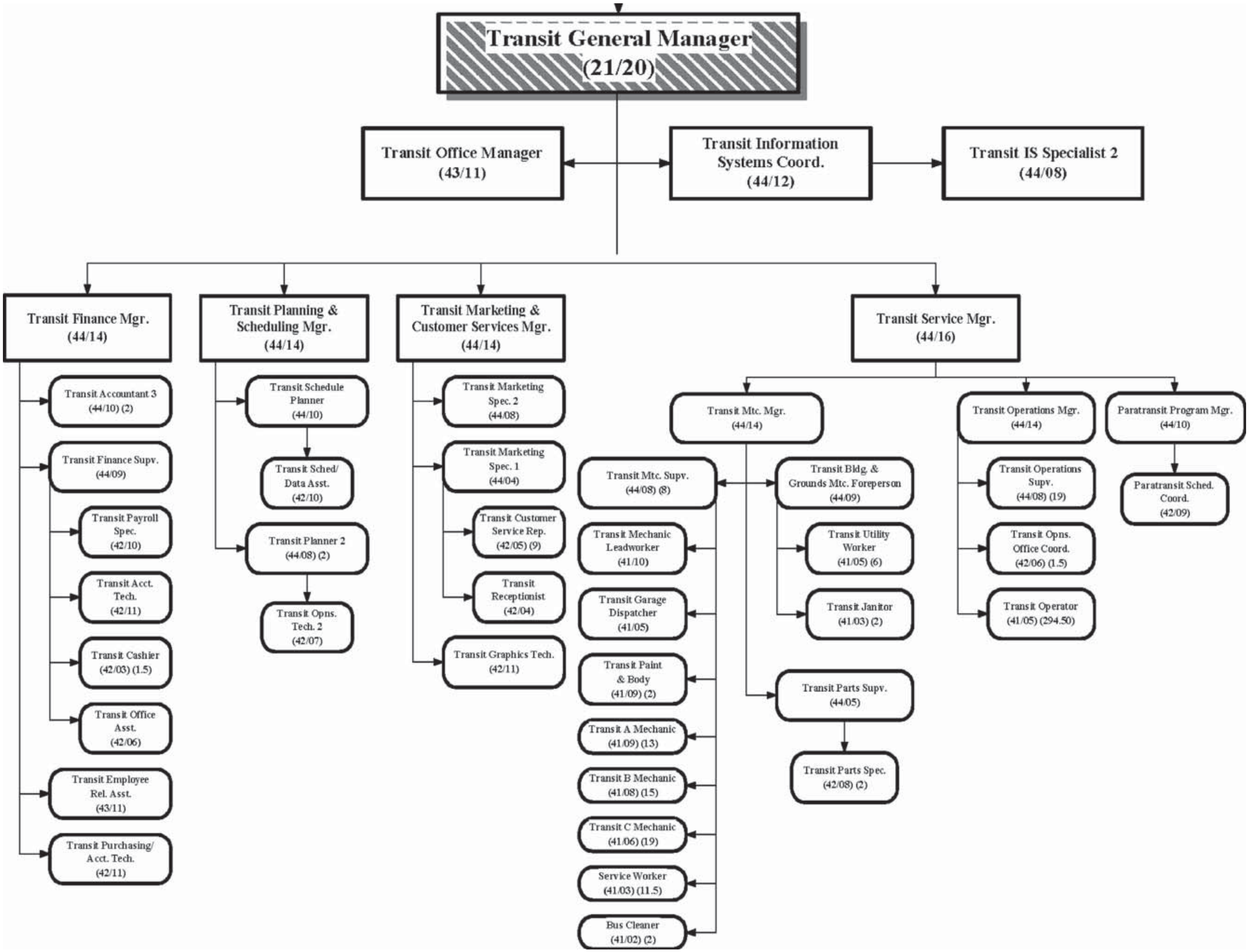

Figure B-1. Madison Metro organizational structure.

integrated, with a single log on for operators. AVL data are radio-transmitted on a one-minute polling cycle, while stop-level data are stored on an on-board computer. The agency is presently developing a real time stop arrival-reporting link on its website using the AVL poll data. Automated internal/external stop announcements are made at more than half of the 2,100 stops in the system.

Beyond the base cash fare, there are a variety of payment/fare options for riders. Options include a 31-day pass (activated on first use); youth semester and summer passes; adult, youth, and senior-disabled 10-ride cards; and unlimited-ride weekend family passes. In addition, Madison Metro has negotiated pass program agreements with the university, several area colleges, the City of Madison, and several area hospitals. Transfers on the system are free.

A breakdown of fare revenue in 2006 shows a substantial share linked to the negotiated pass programs (48.7%), followed by 10-ride tickets (19.7%), passes (17.8%), and cash fares (13.8%). Over time, the share of revenues from cash and 10-ride tickets has been declining, while the share from 31-day passes has been growing.

The introduction of magnetic stripe cards has facilitated recent changes in the pass program. Before cards were deployed, Madison Metro negotiated arrangements with area institutions that guaranteed a base level of funding in exchange for unlimited rides up to an agreed upon threshold. Beyond the threshold, program participants were charged on a per ride basis. Pass program ridership numbers were recorded by operators pressing designated keys on electronic fareboxes. The introduction of magnetic stripe cards has effectively eliminated any concerns that may have existed about the accuracy of the pass program ridership counts. Beginning fall 2007, pass program agreements will be priced on a straight per ride basis. Some of the new program agreements include clauses that limit increases or decreases in revenues from changes in ridership over previous years levels.

Systemwide stop level boarding and alighting data are being recovered by the APCs. Staff noted that passenger load data are not "zeroed out" at the end of each bus trip, and loads thus grow over the course of the day as more people appear to be boarding than alighting. A software fix, such as that described by Furth et al. (2006), will need to be introduced to correct this problem. The accuracy of the boarding and alighting counts also has not yet been systematically verified, as in Kimpel et al. (2003). Staff thus had greater confidence in the ridership counts obtained from fare card and farebox data than from APC data. However, stop level APC data have proved useful to service planners in targeting stop amenity improvements at locations with the greatest passenger volumes.

The final element of Madison Metro's ITS technology package consists of digital cameras, which are installed on 20 buses (10% of the fleet). They are in the process of installing Wi-Fi transmission to enable real time feeds of the camera images to the dispatch center. Concerns about granting external access to the images through the state's open record laws have factored in the decision not to archive camera image data. While the cameras offer a potential means of validating passenger movements recorded by APCs, the two systems are not currently installed on the same buses.

Prior to deploying its ITS technologies, Madison Metro collected very little passenger data. Ride checks were done by staff to collect data for NTD reporting and electronic farebox data provided summary totals for routes along with operator keyed counts associated with pass users. Although the new technologies had been in active service for less than two years at the time of the site visit, staff provided a number of examples of ITS data applications in the areas of customer service, market research, service planning, and scheduling.

Madison Metro has historically relied on customer telephone contacts with service representatives and community meetings as a primary source of customer information. Using the playback feature, they are now able to check vehicle location status in the AVL data archive to help resolve customer complaints.

The agency is engaged in an ongoing stop planning, evaluation, and consolidation process in an effort to improve service. As is often the case in the industry, proposals to relocate or eliminate stops encounter active responses from the community. As illustrated in Figure B-2, Madison Metro used GIS to present APC boarding and alighting data, as well as street and employment data from other city agencies, to communicate information related to a stop closure near the state capitol. In an easy-to-understand map, staff were able to communicate information on stop usage, distance to the nearest alternative stops, the grade that pedestrians would face in walking to other stops, and the number of persons working in the area affected by the proposed stop closure.

In another GIS application, staff drew on APC stop level data and adjacent traffic count data (obtained from the Madison Area Metropolitan Planning Organization) to portray "exposure" at stops in the system for selling advertising space in stop shelters. Stop level passenger movement data were also analyzed by service planners to identify higher traffic locations for adding stop amenities.

The geography of Madison has influenced the design of the transit route network, and consequently places a greater than normal emphasis on on-time performance for effective service delivery. The network converges on the isthmus between Lakes Mendota, Monona, and Wingra, where state and city government, the University of Wisconsin, commercial activity, and regional health services are concentrated. Residential and retail development spread out from both ends of the isthmus around and beyond the lakes. Outlying routes feed

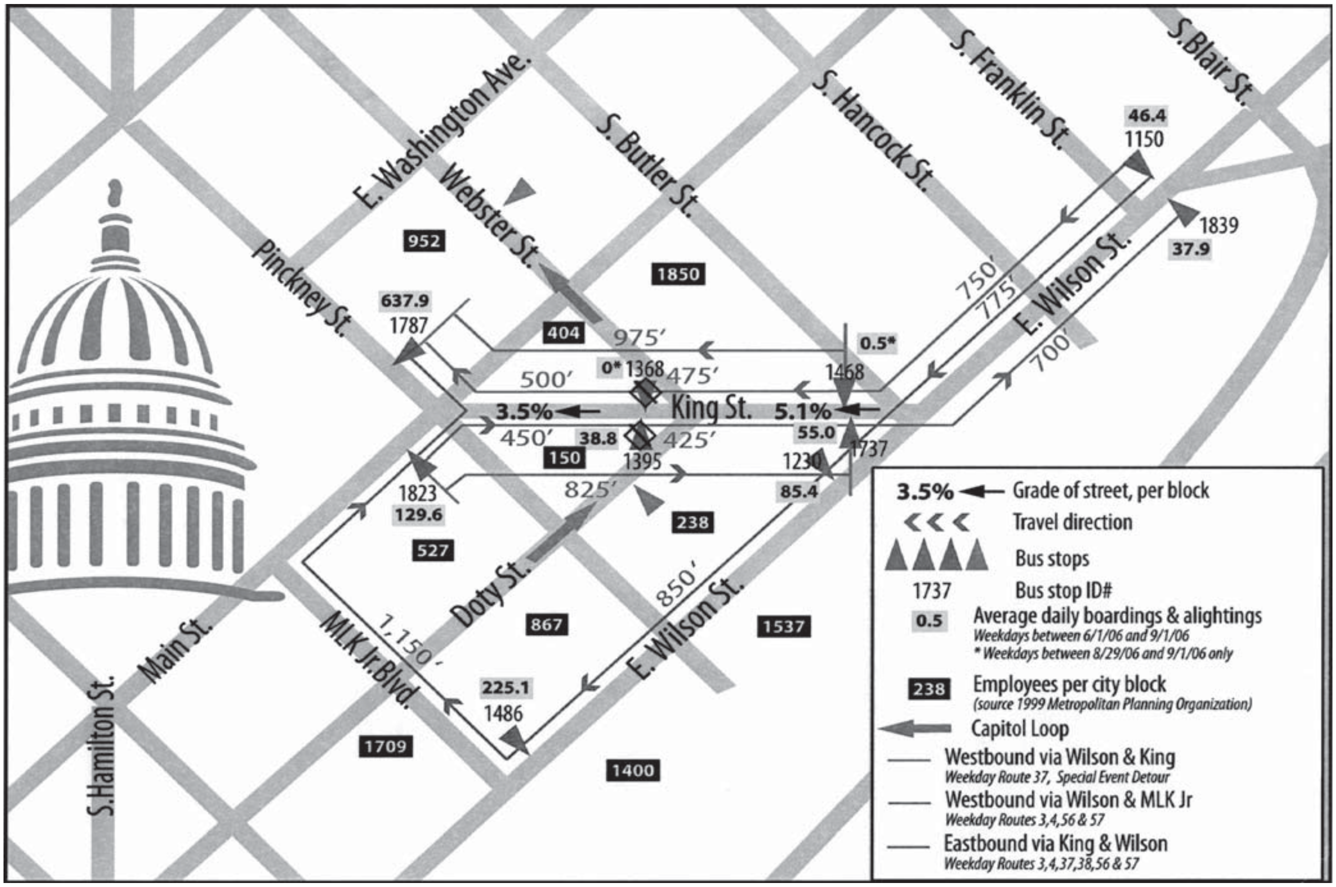

Figure B-2. Presentation of information on a proposed stop closure in Madison.

passengers to four timed-transfer locations, which connect to trunk service that runs through the dense central corridor. Schedules must be written to ensure that the outlying transfers are made and that interlined trunk service departs from the core on time. Schedule writers' jobs have been greatly facilitated by having access to running time data between route time points. Dwell times at stops are also being examined in relation to passenger movements to identify instances where operators have to kill time to maintain the schedule. Overall, schedules have been fine-tuned to reflect actual operating conditions represented in the AVL and APC data. Staff noted that after the revision of schedules fewer complaints were being logged from customers and operators.

Generally, Madison Metro has not been very heavily engaged in comprehensive customer or population surveys. Its last system rider census was completed in the 1990s, and it has recently hired a contractor to undertake a rider/non-rider perceptions survey. The survey work undertaken by staff has focused on specific customer groups or locations. Staff recently completed a Web-based survey targeting persons with disabilities to assess preferences for lifts versus ramps to board vehicles. In areas where the agency is assessing opportunities for improving service, market research staff has used the city's GIS to obtain addresses of residents within 1/4 mile for a mail survey of service preferences.

With less than two years experience working with ITS data, Madison Metro staff have not fully tapped the potential that they see in its applications to market research, planning and scheduling issues. One of the attributes characterizing transit use in Madison is the seasonality in ridership patterns. In 2006, for example, July boardings were just 55% of the November totals. Such seasonal differences largely reflect the travel activities of area university and college students and faculty. Staff would like to gain a better understanding of the travel patterns of this important segment of their market. Examination of APC boarding and alighting data by month would provide insights into the stops and routes that are most affected by this group's travel. Examination of the sequence of their card transactions, following the procedure developed by Rahbee and Czerwinski (2002), would also provide a better understanding of their travel paths through the system. The insights gained from such analysis would allow staff to better adapt service levels and schedules to seasonal travel demands.

There is also an interest among market research and planning staff in making greater use of GIS in analyzing census data. Applications were identified in two contexts. First, staff are interested in developing customer profiles along corridors where service is already provided. Second, there is an interest in identifying the areas that are currently not served or underserved where the demographics suggest the existence of latent demand for transit.

Performance Indicators

Madison Metro's management meets monthly with the Parking and Transit Commission. A variety of fixed route operating performance indicators are reported to the commission, covering service supplied and consumed (vehicle miles/hours; boardings/transfers), service quality (lift usage; vehicle/passenger accidents), customer service (complaints; compliments; suggestions), and maintenance (road calls; vehicle inspections). Detailed boarding statistics are also reported by time period and by route, along with corresponding productivity measures (boardings per revenue hour). Routes with boardings per revenue hour below 60% of the systemwide average are flagged for evaluation.

Performance indicators also cover revenues (by source) and operating expenses. Associated productivity measures—farebox recovery, passenger revenue per trip, and operating cost per revenue hour and passenger trip—are reported. Madison Metro has identified a dozen peer properties and compares its revenue and productivity indicators to the composite peer averages. Data for peer properties are taken from the NTD.

Presently, the performance indicators reported to the commission do not draw on ITS data, with the exception of boardings, which are based on fare card and farebox data. Fare policy discussions would be facilitated by regular reporting of activity across alternative fare media. Properties with AVL systems are now commonly reporting on-time performance. This would likely be a useful performance indicator for Madison Metro, given the importance of timed transfers in its system.

Issues, Observations, and Challenges

Management

Madison Metro Transit is beginning to make full use of the benefits of leveraging market research with data from ITS technologies. Among the three case study properties, ITS technology deployment has occurred most recently at Madison Metro. Also, even after accounting for is relatively smaller size, the level of staff resources available is more limited than those available at the other case study properties. For example, data from the 2005 National Transit Database shows that while Madison Metro ranks 52nd overall in vehicles operated in maximum service (VOMS), it ranks 70th overall in total administrative employees. While an institution-level employment measure does not necessarily reflect IT and market research staff levels, it does highlight the challenges facing the agency in integrating AVL, magnetic stripe card, and APC data for market research and planning.

The transit ITS literature emphasizes the importance of management support, particularly in the post-deployment period where data archiving and development of analysis tools are oftentimes starved for funding. Having been directly involved in the statewide transit ITS procurement process, Madison Metro's general manager showed a depth of insight and commitment that was uncharacteristic of his peers. He stressed that the technologies represented a direct investment in customer satisfaction (by providing stop annunciation and vehicle arrival information) and an indirect investment in developing new markets (by recovering data that would improve understanding of existing customers and help in identifying and reaching out to new customers). He suggested that the systems and the information they provided represent "the wave of the future" for the transit industry, deserving more funding.

Market Research

The market research function at Madison Metro is not as fully developed as it is at CTA and TriMet. As is the case at most smaller agencies, market research is not used in an ongoing and strategic capacity; rather, it is used tactically, with studies being implemented on an ad hoc basis when a need for specific information is identified. Although systematic collection of market data is not present, staff is aware of the existence and benefits of ITS data and have been creative in applying such data in selected circumstances. An example of creative use of ITS data was the combination of traffic count and passenger data at stops to represent advertising exposure.

With the emergence of ITS data at Madison Metro, there is an opportunity to develop the agency's market research function through analysis of customer data from fare cards and APCs, and service delivery data from AVL. To capitalize on the opportunity, the two marketing specialists currently dedicated to core activities could be supplemented by a market research analyst dedicated to drawing ITS data into Madison Metro's market research program.

ITS and IS

Madison Metro is transitioning from an environment in which there was no consistent data collection to one where ITS operating and passenger data streams pose several challenges. The data support staffing that was embedded in the market research and planning units at CTA and within the scheduling and planning functions at TriMet, which proved important in their efforts to leverage ITS data, does not presently exist at Madison Metro. The agency has been fortunate in dealing with this limitation by virtue of the fact that its IS manager is a former service planner and operator who brings an understanding of market research and operations practice that is not normally found in that position.

While there is adequate IS staffing to manage ITS data, there is a need for additional staff to develop applications and customized reports. The vendor-provided reporting software (Ridecheck Plus) was not considered very useful without customization. Additional IS staff would also open up an opportunity to tap the intellectual resources of the university through internships, which has not been pursued to date because of the limited time staff have to take on management of this activity. Moreover, the University of Wisconsin administers a U.S. DOT-sponsored regional University Transportation Center (UTC) whose theme (optimization of transportation investment and operations) appears to be compatible with Madison Metro's need for developing new applications that leverage ITS data. University faculty and graduate students could potentially be engaged in UTC-supported research or technology transfer activities that would help to meet this need.

While the coordinated statewide ITS procurement program eased the burden that each property faced in the process, the "one size fits all" approach meant that the systems acquired may not have been best suited to each property. Among the alternative fare payment technologies, smart cards were dropped from consideration fairly early in the process, and there was a concern that the magnetic stripe card technology selected represented a second best choice for Madison Metro.

There were several observations on the technology deployment and procurement processes. First, it was necessary to re-geocode the stops in the system to achieve the accuracy required for AVL operation. Second, staff emphasized that it was important to obtain full documentation of the systems. Third, staff thought that the procurement and deployment processes would have been improved by collecting more information from other transit properties that had already gone through the processes.

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Madison Metro Staff Interviewed

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Charles Kamp, General Manager
Julie Maryott-Walsh, Manager, Marketing and Customer Service
Sharon Persich, Manager, Service Planning and Scheduling

APPENDIX C

TriMet Case Study

TriMet provides fixed route bus and light rail service to the Portland, Oregon, metropolitan area. The transit system comprises 91 bus routes, 77 of which connect to a 4-route, 44-mile light rail network. Its fleet of 614 buses and 105 rail cars carried over 95 million boarding rides in 2006. In addition, TriMet is contracted to operate the downtown Portland Streetcar. A noteworthy feature of the transit system is Fareless Square, a downtown zone within which travel is free.

Preliminary analysis pointed to the following reasons for selecting TriMet as a case study for this Guidebook:

- TriMet was an early adopter of APC technology, and leveraged its APC experience in the design of its AVL system. The agency has a strong reputation in the industry for its innovative uses of archived AVL and APC data in market research, performance monitoring, scheduling, and service planning.
- TriMet's market research program is comprehensive, and the agency has pioneered the development of new attitudinal metrics for understanding customer perceptions. Market researchers at TriMet have also used ITS data to leverage traditional market research practices, and have linked customer perception and satisfaction research to AVL and APC data.
- TriMet has developed its GIS capabilities within a fully integrated enterprise data environment that includes archived data from ITS technologies. There are a number of high-end GIS users employing ITS data in market research and planning applications.

The research team met with TriMet staff in January 2007.

Organizational Structure

TriMet's organizational structure includes five major divisions:

- Finance
- Capital Projects
- Government Affairs
- Operations
- Communications and Technology

The agency's market research unit is housed in the Communications and Technology (CT) division, as is the information technology (IT) unit. The service planning and scheduling units reside in the Operations division. Over time, there has been a centralization of functions within IT that had previously been maintained in other units throughout the agency, consistent with the development of TriMet's enterprise data system. The IT unit is also responsible for developing enterprise applications utilizing archived ITS data, many of which involve GIS.

TriMet's Experience With ITS Technology

TriMet's experience with APC technology dates from a demonstration project in the early 1980s. In the course of this project, a severe economic downturn in the region forced significant service cuts and the release of the agency's entire ride checking staff. Thus the APCs offered the only means of recovering passenger data for internal and NTD reporting. A staff person was assigned responsibility for "fixing the bugs" in the system, including problems with maintenance, trip and stop referencing (which were based on odometer and time clock stamps in pre-AVL days), and balancing block level boardings with alightings.

Although considerable success was achieved in overcoming operational problems with the APCs prior to AVL deployment, usable data recovery rates rarely exceeded 25%. With a fleet penetration rate of about 15% in 1990, the APCs were thus barely able to satisfy TriMet's data needs for NTD reporting. A study was done to validate the accuracy of passenger counts and to design a vehicle/APC assignment plan to satisfy NTD sampling requirements (Strathman and Hopper

1991). This plan was implemented for several years, but problems often occurred at the garage level in assigning APC-equipped buses to NTD sample blocks. With improvement in the agency's financial condition in the 1990s, passenger counting for NTD reporting was contracted out and manually recovered. At that point the APC buses were redeployed to support service planning information needs.

Despite the initial problems, TriMet's experience with APCs proved valuable in planning its AVL system. The AVL project team was headed by the staff person who had been responsible for NTD reporting and also included the staff person who had been responsible for maintaining the APCs. They recognized that AVL's improved location referencing capabilities would, when integrated with APCs, yield much higher rates of successful passenger data recovery. Specifications for the AVL system thus included a capability to produce and store passenger and operating data records at the stop level. Bandwidth limitations prevented transmission of the large volume of stop level data records over the radio system, requiring storage on an on-board computer.

The requirement of location-defined data recovery distinguished the specification of TriMet's AVL system from other GPS-based systems that were deployed in the 1990s. All AVL systems featured transmission of real time vehicle location status data to dispatchers on a 30-90 second polling cycle. While this information had considerable value in support of operations management, and has since been extended to customer information applications (e.g., in posting estimated vehicle arrival times at selected stops and on the Web), it was incompatible with applications requiring information about specific locations (e.g., stops, time points, route origins and destinations).

A side benefit from on-board storage of AVL data was a reduction in the cost of APC units. With data storage computers already on board to serve the AVL system, the cost of adding APC units in the late 1990s fell to about $1,000/vehicle. Thus, TriMet decided to specify APCs in all new bus acquisitions. Presently, about 75% of the bus fleet and 25% of the light rail fleet are APC-equipped. While this level of penetration is higher than what is needed for NTD and internal ridership reporting, it allows staff to analyze operations and evaluate service in ways that are unique in the industry.

A final feature of TriMet's AVL system that distinguished it from others deployed in the 1990s was a control head installed near the vehicle operator. The control head displays the vehicle's status in relation to its schedule (minutes early/late), and a keypad allows the operator to send pre-programmed text messages to the dispatch center (e.g., 74 = "Mechanical Problem—Out of Service"). The text message records are stored for offline analysis.

The AVL system was deployed in 1998. A study compared system performance a year after deployment to performance prior to deployment (Strathman et al. 2000). Although there were no changes in operations practices during the study period, improvements were observed in on-time performance, running times and running time variation. It was hypothesized that the improvements resulted from the "instrumentation effects" of the new system associated with operators having better knowledge of their schedule status and dispatchers having better knowledge of vehicles' operating status.

TriMet's estimated breakdown of fare revenue in fiscal year 2008 is 39% farebox (cash), 9% pre-paid ticket sales, and 52% flash pass sales. TriMet does not have advanced electronic fare payment technologies, such as magnetic stripe or smart cards. Electronic registering fareboxes have been in use since 1989. The fareboxes are not integrated with the AVL system, and reporting is thus limited to daily cash receipt totals. Ticket vending machines have also been in service since 1986, with reporting limited to time, location, and fare instrument purchased. Most of the ticket vending machines are located at light rail stations. Generally speaking, TriMet's electronic fare payment technologies are not used for service delivery or market research analysis.

The remaining technologies include automated phone systems and the Web. Tracking software has been used to log Web visits since 2002. Information is thus available on Web links providing trip planning services and real time vehicle arrival times at stops ("Transit Tracker"). Customers can also report compliments, suggestions, and complaints on the Web. The automated phone system provides trip planning, arrival time, and customer feedback services, all of which are logged.

ITS Data Management

A central "core" set of data is maintained and managed as a foundation for all TriMet ITS initiatives. The architecture of the agency's enterprise data system is illustrated in Figure C-1. The diagram reflects the holistic nature of the data environment and the importance of integration of ITS systems and applications. This ensures that the publication and dissemination of data are accurate and consistent across all systems.

Base detailed features of the transit system (e.g., routes, stops) are represented and maintained in *Definition & Maintenance* tables. This information is used in conjunction with vehicle itineraries, produced by HASTUS scheduling software, to prepare the published schedule. After the data are validated, the prepared schedules are written to cards that are inserted by vehicle operators in the log in process.

Vehicles in service recover and store data records from the AVL and APC systems. The data records (including schedule and AVL-APC operating data) are downloaded at the end of each day at the garages. Post processing is then undertaken by Operations staff to ensure the validity of the recovered data.

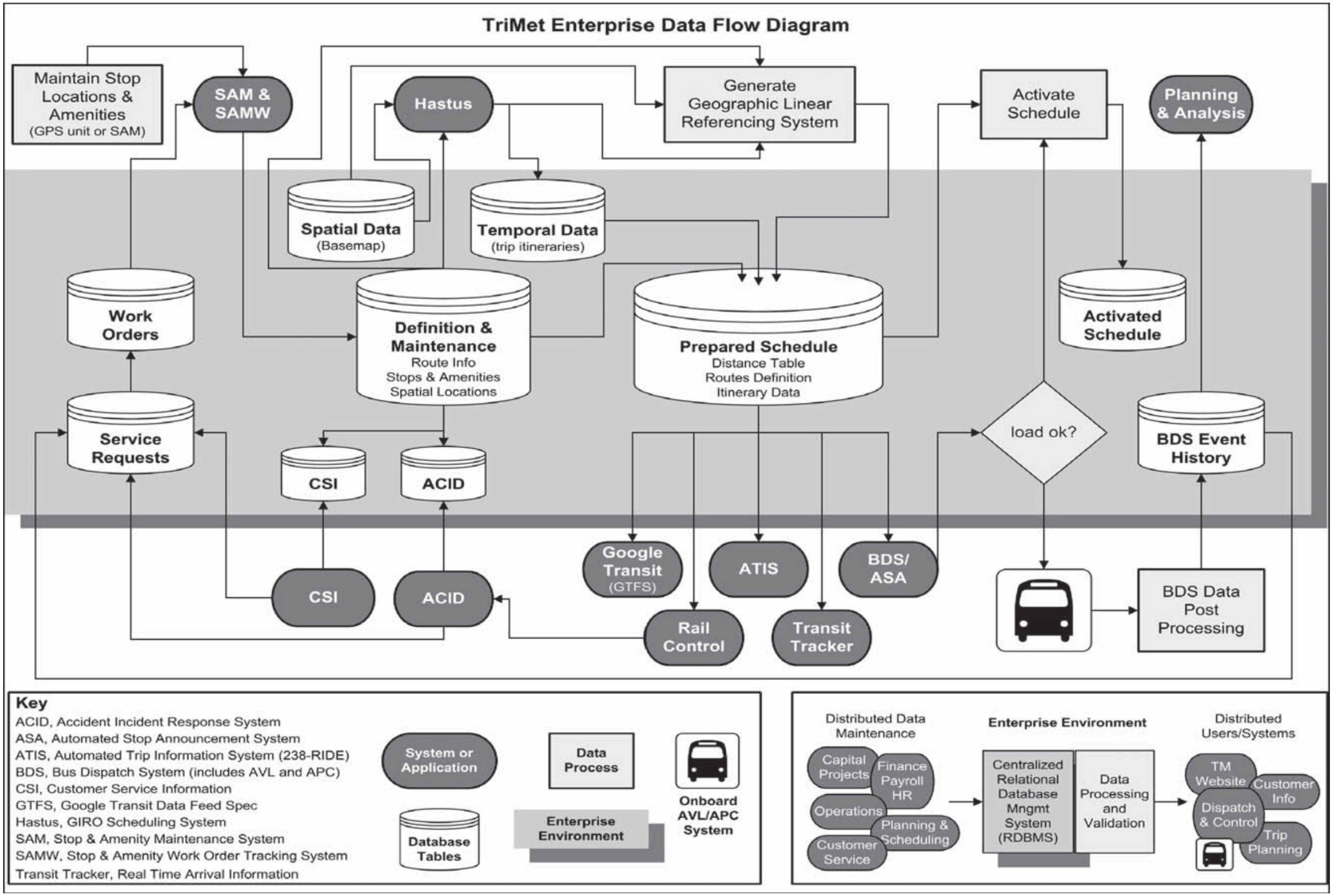

Figure C-1. TriMet's enterprise data system.

Post processing involves a number of steps: (1) matching vehicles' AVL data records to their schedules and the base map of stops and time points associated with the assigned work; (2) event data recorded at locations other than those represented in the base map are assigned to base map locations (examples include instances where a vehicle drops off or picks up passengers between scheduled stops, records for temporary re-routes, the record of a vehicle's maximum speed between stops, or an event record); (3) screening to identify extreme values, which may indicate a malfunctioning unit (records with extreme values are retained, but flagged to indicate that the data may be suspect); (4) "zeroing out" passenger loads at the service block level, and proportionately adjusting boarding and alighting data to correspond to the block load adjustment.

After post processing, data are forwarded to *BDS (Bus Dispatch System) Event History* tables. Event history data, accumulating at a rate of about 600,000 records per day, are then ready to be accessed by staff for analysis.

Selected data, such as operator-keyed event records related to stop maintenance and repair, automatically generate *Service Requests* that are then evaluated by staff and (if required) converted into *Work Orders* for work. The status of a work order is monitored by the *Stop and Amenities Work Order Tracking System (SAMW),* and the history is retained for future reference.

Following the stop maintenance and repair example, the process might also be initiated through the *Customer Service Information (CSI)* program. In this case the service request originates from a customer Web or phone contact. In addition to directing the information to *Service Requests*, the customer contact would also be logged in a *CSI* table.

Data from the *Prepared Schedule* tables are also linked to several other customer information systems. The *Automated Trip Information System (ATIS),* supports the trip planning program offered through the Web and by phone. *Transit Tracker* supports the phone and Web-based program that provides next arrival times. Data are also generated in the Google Transit Feed Spec (GTFS) format and made available for public access for external applications, such as Google Transit.

The final operations-related component of the enterprise data system is the *Accident Incident Response System (ACID)* and tables, which contain data from incident reports.

Spatial data are directly maintained in Oracle tables to ensure consistent integration of ITS data across the enterprise system and to facilitate access for GIS applications. A number of GIS applications have been developed to support desktop mapping and analysis of data from various Oracle tables. For example, the Real Time Bus Mapper is a Web-based application that displays the current location of buses in service. Other GIS applications have been developed to map data from the *Work Order, CSI, Event History, and Definition & Maintenance* tables.

GIS staff prepare a basemap for systems throughout the agency for import, including HASTUS, the Automated Trip Information System (ATIS), and the Trapeze Paratransit system. GIS data collection is used to collect location and amenity information for features of the transit system.

As the description of post processing activities indicates, units throughout TriMet are directly responsible for maintaining data in Oracle tables within the enterprise data system. GIS staff adhere to the same IT standards (Oracle, Java, Linux) and the same Systems Engineering approach to application development.

The evolution of the enterprise data system is guided by system integration strategies that include a database design review process and procurement policies for new systems.

Service Delivery Monitoring and Analysis

Few, if any, transit properties in the U.S. have developed a service delivery analysis and monitoring capability comparable to what TriMet has achieved with its archived AVL and APC data. These achievements are a consequence of the forethought given to the specification of ITS data recovery and archiving, the high penetration of APC units in the fleet, and the efforts of highly skilled staff analysts.

The service delivery monitoring and analysis activities described in this section can be distinguished between regular performance reporting, which usually occurs quarterly, and ad hoc analysis, which is undertaken to address specific needs or issues. However, it should be emphasized that regular reporting activity and ad hoc analysis have been strategically related in that the content and coverage of performance reports have evolved to incorporate what has been learned from ad hoc analysis.

Quarterly performance reports are posted on the agency Intranet in both pdf and Excel format. The trip level summary report serves as the cornerstone of quarterly performance reporting. The report provided detailed information on passenger activity, on-time performance, and vehicle running times for every scheduled trip in the system. Selected information from the spring 2007 trip performance report for scheduled AM Peak period inbound trips on the Route 14-Hawthorne is shown in Table C-1. Capacity utilization is represented by the average maximum passenger load per trip. Information on the percentage of trips where the maximum passenger load exceeds 80% of a vehicle's maximum design capacity provides an indicator of both the variance in capacity utilization and the extent of excess demand.

The scheduled running time for each trip serves as a benchmark against which actual running times are compared.

Table C-1. Route 14 Hawthorne trip level summary report, spring 2007 (AM peak inbound trips).

Start Time	Avg. Max Load	Percent Over Capacity	Scheduled Run Time	Median Run Time Less Idle	60th% Run Time Less Idle	80th% Run Time Less Idle	Percent On Time	Percent Early	Percent Late
7:02 AM	45	0%	0:36:00	0:31:26	0:32:18	0:33:19	90%	5%	4%
7:06 AM	27	0%	0:36:00	0:35:10	0:35:44	0:36:48	97%	1%	2%
7:10 AM	43	18%	0:37:00	0:36:14	0:36:38	0:38:20	93%	6%	1%
7:13 AM	46	0%	0:38:00	0:36:37	0:37:18	0:37:58	94%	2%	4%
7:16 AM	31	0%	0:38:00	0:35:49	0:36:14	0:37:36	97%	2%	1%
7:19 AM	31	0%	0:38:00	0:35:39	0:36:12	0:37:38	98%	1%	0%
7:24 AM	49	24%	0:38:00	0:36:25	0:37:08	0:38:14	97%	3%	1%
7:29 AM	32	5%	0:39:00	0:35:43	0:36:32	0:37:21	95%	1%	4%
7:34 AM	38	8%	0:39:00	0:36:40	0:37:32	0:39:18	99%	0%	1%
7:38 AM	19	0%	0:39:00	0:34:44	0:35:02	0:36:08	86%	12%	2%
7:43 AM	40	4%	0:39:00	0:36:46	0:37:22	0:38:10	96%	4%	0%
7:47 AM	33	2%	0:39:00	0:35:56	0:36:36	0:37:58	98%	2%	0%
7:52 AM	40	10%	0:39:00	0:35:48	0:36:12	0:37:32	99%	1%	0%
8:04 AM	45	17%	0:39:00	0:35:28	0:35:59	0:37:47	89%	3%	7%
8:10 AM	40	50%	0:39:00	0:33:28	0:34:00	0:35:42	95%	3%	2%
8:17 AM	35	8%	0:38:00	0:36:14	0:36:44	0:38:20	95%	2%	3%
8:26 AM	49	31%	0:38:00	0:33:14	0:34:25	0:35:49	98%	1%	0%
8:33 AM	31	2%	0:38:00	0:35:38	0:36:14	0:37:42	91%	7%	2%
8:44 AM	35	5%	0:36:00	0:35:06	0:35:25	0:37:27	96%	2%	2%
8:53 AM	40	9%	0:36:00	0:34:48	0:35:36	0:37:18	97%	2%	1%
9:04 AM	42	15%	0:36:00	0:37:22	0:37:38	0:38:56	98%	0%	1%

Traditional scheduling practice has been to set scheduled running times to approximate the median, although standards exceeding the median have become more common. Actual running times in the quarterly trip report are given for the median, 60th, and 80th percentile of the distribution. A noteworthy feature of the running time statistics in the report is that they have been adjusted to remove excess dwell time, using threshold dwell times required to service stops on the route. Dwells exceeding the threshold are interpreted as likely to reflect holding actions associated with maintaining the schedule.

Systematic departures from scheduled running times signal a need to add or trim running times from the schedule. When a decision is made that there is a need to adjust the schedule, plots of actual running times are also produced to aid the process. These plots are similar to those described in the CTA case study. Staff commented that three schedule writers can now do the work that used to require six, and that schedule adherence has improved over time despite worsening traffic congestion. Also, the running time reports are revealing opportunities to remove time from schedules, where operator and customer feedback in the past mostly focused on the need to add time.

On-time performance information is presented in the last three columns of Table C-1. "Late" is defined as departures that are more than 5 min after the scheduled departure time; "early" is defined as departures that are more than 1 min before the scheduled departure time; and "on time" is defined as departures that are between 1 min early and 5 min late. There is a readily apparent relationship between scheduled running time, actual running time, and on-time performance. For example, when scheduled running is inadequate, the percentage of late departures increases and the percentage of on-time and early departures declines. In the case of the trips covered in Table C-1, scheduled running times are generally greater than the actual median, 60th percentile, and 80th percentile values, indicating that the schedule provides more than adequate time for operators to complete their trips. Consequently, on-time performance is quite high, and the incidence of early departures generally exceeds the incidence of late departures.

Although trip report information on mean maximum passenger loads indicated that there was generally sufficient capacity, the variance in maximum passenger loads among blocks of trips on routes during peak service periods also suggested that deviations from scheduled headways were contributing to instances of overloading. This was confirmed by ad hoc statistical analysis of the relationship between headway deviation (i.e., "bus bunching") and passenger loads. Figure C-2 illustrates the relationship for AM Peak inbound trips on Route 14-Hawthorne. In this plot, the average load for vehicles maintaining their scheduled headway (0.00 headway delay) is approximately 45 passengers. For vehicles whose actual headway has grown to two minutes greater than schedule, average loads are about 55 passengers. Conversely, for vehicles whose actual headway has decreased to two minutes less than schedule, average loads fall to about 35 passengers. Thus, it was concluded that the solution for managing (leveling) passenger loads lies in improving headway management.

Further statistical analysis exploring the root causes of headway deviations identified late departures from garages and route origins as principal contributors to the problem

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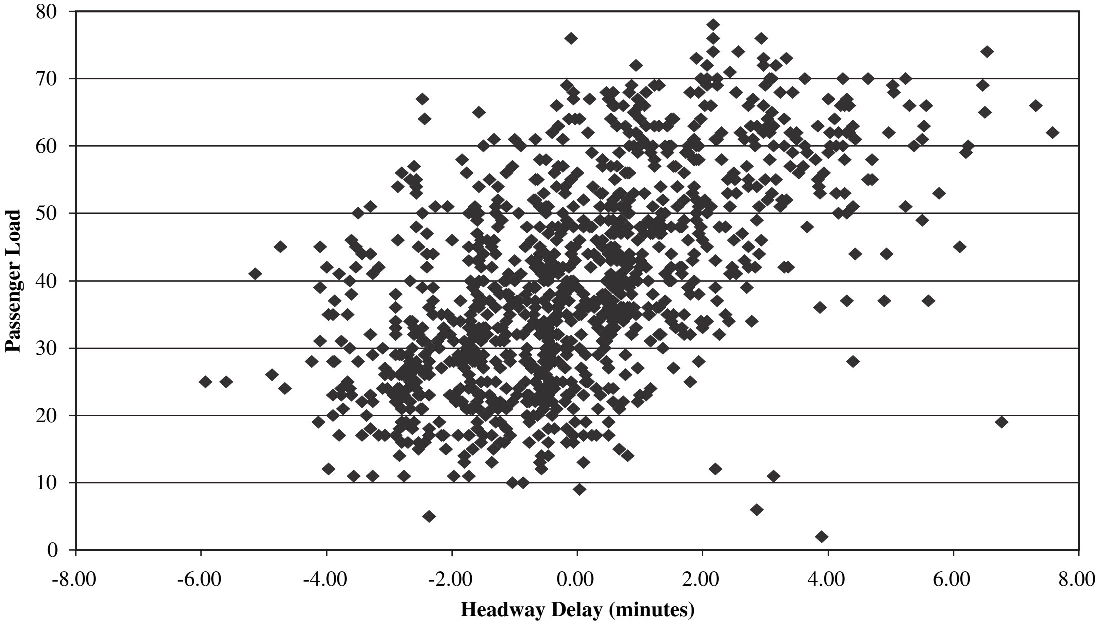

Figure C-2. Passenger loads and headway delay on Route 14-Hawthorne. (AM peak inbound trips at peak load point)

(Strathman et al. 2003). Tabulations of AVL data exhibited instances of habitual late departures from origins (following adequate layover) and from garages. Regular reporting of these tabulations to field supervisors and garage managers followed. (It should be emphasized that TriMet supervisors and managers cannot pursue disciplinary action on the basis of evidence from AVL and APC data. Uses of the data are limited to facilitating accepted operations management practices.)

For customers, deviations from scheduled headways translate into increased waiting time and a greater likelihood of being passed up by an overloaded vehicle. It has long been understood in the transit industry that waiting time at stops and stations is considered by customers to be much more onerous than their line haul time or time spent in accessing stops or final destinations.

TriMet staff developed a measure to capture the additional time passengers spend waiting for scheduled service when vehicles' actual headways deviate from their scheduled headway. This measure, termed "excess wait," is reported quarterly by route, direction, and time period. Table C-2 presents sorted values of excess wait time for the spring 2007 signup. In this case the excess wait value in the first row of the table indicates that passengers on outbound PM Peak trips on Route 8-NE 15th Ave. waited three and a half minutes longer for service than they would have had headways been maintained.

Headway adherence values are also reported in Table C-2. These values represent the percentage of instances in which actual headways are within 50% of their scheduled values at time points for the corresponding service blocks. Headway adherence and excess wait are generally, but not directly, related. For example, for a given percentage value of headway adherence, excess waiting time tends to be greater for larger than for smaller scheduled headways.

It is apparent in Table C-2 that excess wait time and on-time performance are related. In contrast to the high on-time performance reported in Table C-1, the Table C-2 values associated with the worst excess wait situations are much lower. Also, it is apparent that excess waiting and the gap between scheduled and actual headways are the result of lateness.

TriMet's excess wait measure is based on the same headway and boarding data as the CTA's wait index measure. In addition to AVL data, which are recovered fleet-wide, both measures require extensive recovery of passenger data. At the CTA, these data are recovered from smart and magnetic stripe card usage, while at TriMet the data are recovered by APCs. Both CTA's wait index and TriMet's wait time measures are easily understood. However, an advantage of TriMet's wait time measure is that, given a monetary value of waiting time (e.g., Mohring et al. 1987), one can directly determine the impact on customer welfare from TriMet's measure.

Another benefit from access to comprehensive passenger data at TriMet is evident in the agency's approach to evaluating the level of service supplied to routes. Analogous to standard practice in evaluations of highway capacity utilization, TriMet calculates passenger volumes in relation to vehicle capacities over varying hour-long time periods. An example is shown in Table C-3, which presents sorted weekday volume/capacity measures for the spring 2007 signup. In this example, the highest capacity utilization in the system occurred with outbound

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Table C-2. Headway adherence and excess wait time, spring 2007 (sorted by excess wait time).

Route, Direction, Time of Day	Daily Trips	On Time	Early	Late	Scheduled Headway	Headway Adherence	Excess Wait (min.)
8-NE 15th Ave - Outbound - PM Peak	14.0	45%	3%	52%	8:58	48%	3:27
4-Fessenden - Outbound - PM Peak	10.0	46%	4%	50%	12:37	49%	3:27
15-Belmont - Outbound - PM Peak	20.0	63%	2%	34%	6:14	49%	3:15
8-Jackson Park - Inbound - PM Peak	15.0	57%	1%	42%	8:19	47%	3:10
96-Tualatin/I-5 - Outbound - PM Peak	10.0	60%	0%	40%	10:57	67%	2:47
64-Marquam Hill/Tigard TC - Inbound - AM Peak	5.0	96%	0%	4%	19:50	90%	2:43
4-Division - Outbound - PM Peak	15.0	65%	6%	29%	7:58	54%	2:33
4-Division - Inbound - PM Peak	10.0	67%	4%	29%	12:43	59%	2:23
51-Vista - Inbound - AM Peak	8.4	89%	8%	2%	17:05	91%	2:11
20-Burnside/Stark - Outbound - PM Peak	7.0	66%	6%	27%	15:14	75%	2:07
17-Holgate - Outbound - PM Peak	11.0	59%	7%	33%	11:00	65%	2:07
94-Sherwood/Pacific Hwy Express - Outbound - PM Peak	14.0	73%	0%	26%	9:21	66%	2:05
72-Killingsworth/82nd Ave - Inbound - PM Peak	16.0	73%	7%	20%	7:42	50%	2:02
99-McLoughlin Express - Outbound - PM Peak	8.0	86%	0%	14%	17:09	84%	1:59
17-NW 21st Ave/St Helens Rd - Outbound - PM Peak	8.0	42%	3%	55%	15:00	75%	1:51
15-NW 23rd Ave - Outbound - Midday	31.0	53%	8%	39%	13:27	65%	1:48
4-Division - Inbound - AM Peak	15.0	89%	2%	9%	7:48	59%	1:43
32-Oatfield - Outbound - PM Peak	6.0	74%	4%	22%	24:34	88%	1:43
9-Powell - Outbound - PM Peak	14.0	62%	7%	32%	8:03	64%	1:42
12-Barbur Blvd - Outbound - Night	19.0	64%	3%	33%	20:08	81%	1:39
71-60th Ave/122nd Ave - Inbound - Midday	27.0	82%	5%	14%	16:18	76%	1:39
15-NW 23rd Ave - Outbound - PM Peak	8.0	48%	8%	44%	15:00	70%	1:38
4-Fessenden - Outbound - Night	23.0	71%	5%	24%	19:52	83%	1:34
72-Killingsworth/82nd Ave - Outbound - PM Peak	16.0	80%	5%	15%	7:43	58%	1:34
8-Jackson Park - Outbound - Midday	32.0	71%	3%	27%	13:11	80%	1:33
15-NW 23rd Ave - Outbound - AM Peak	22.0	72%	5%	24%	5:42	49%	1:33

Table C-3. Weekday peak hour capacity, spring 2007 (sorted by maximum achievable capacity utilization).

Route	Dir.	Begin Time	End Time	Location	Trips	Hourly Load	Load/Seat Capacity	Load/Achievable Capacity
8-Jackson Park	Out	5:02 AM	6:01 AM	SW 3rd betw. Oak & Stark	1	53	123%	95%
MAX Blue Line	Out	4:10 PM	5:09 PM	Pioneer Sq. South MAX Sta.	6	1,470	191%	92%
61-Marq. Hill/Beaverton TC	Out	3:42 PM	4:41 PM	SW Campus Dr & Terwilliger	1	52	120%	92%
72-Killingsworth/82nd Ave	In	12:08 PM	1:07 PM	NE 82nd & MAX Overpass	5	256	131%	92%
MAX Blue Line	Out	4:20 PM	5:19 PM	Pioneer Sq. South MAX Sta.	7	1,694	189%	91%
72-Killingsworth/82nd Ave	Out	4:18 PM	5:17 PM	SE 82nd & Powell	6	303	129%	90%
72-Killingsworth/82nd Ave	In	12:18 PM	1:17 PM	NE 82nd & MAX Overpass	5	250	128%	89%
MAX Blue Line	Out	4:38 PM	5:37 PM	Pioneer Sq. South MAX Sta.	7	1,650	184%	89%
72-Killingsworth/82nd Ave	Out	7:59 AM	8:58 AM	SE 82nd & Powell	5	248	127%	89%
72-Killingsworth/82nd Ave	Out	4:09 PM	5:08 PM	SE 82nd & Powell	7	345	126%	88%
61-Marq. Hill/Beaverton TC	Out	4:12 PM	5:11 PM	SW Campus Dr & Terwilliger	2	98	114%	88%
88-Hart/198th Ave	Out	12:16 PM	1:15 PM	Beaverton Transit Center	1	28	100%	88%
MAX Blue Line	Out	4:47 PM	5:46 PM	Pioneer Sq. South MAX Sta.	6	1,395	182%	87%
72-Killingsworth/82nd Ave	Out	7:41 AM	8:40 AM	SE 82nd & Powell	6	293	125%	87%
72-Killingsworth/82nd Ave	In	2:45 PM	3:44 PM	NE 82nd & MAX Overpass	8	391	124%	87%
6-M. L. King Jr Blvd	Out	2:58 PM	3:57 PM	NE Grand & Pacific	3	146	117%	87%
15-Belmont	Out	6:20 PM	7:19 PM	SW Salmon & 5th	4	194	125%	87%
72-Killingsworth/82nd Ave	Out	7:49 AM	8:48 AM	SE 82nd & Powell	6	291	125%	87%
8-Jackson Park	Out	5:17 AM	6:16 AM	SW 3rd betw. Oak & Stark	2	97	118%	86%
4-Division	Out	2:13 PM	3:12 PM	SE Division & 12th	4	193	121%	86%
72-Killingsworth/82nd Ave	Out	7:05 PM	8:04 PM	SE 82nd & Powell	4	193	124%	86%

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service on Route 8-Jackson Park at SW 3rd Ave. between Oak and Stark St. during the hour period beginning at 5:02 AM. A single scheduled trip provided service during the period and its average hourly load was 53 passengers. This load was 123% of the seat capacity of service supplied and 95% of the maximum achievable vehicle capacity.

Examining service utilization over blocks of trips gives service planners a better sense of when and where additional capacity is needed. Probably the greatest utility from this approach comes in evaluating capacity utilization in corridors served by multiple routes. Here, passenger loads and vehicle capacities can be easily aggregated over routes and trips in the corridor, providing a capacity utilization measure that is more consistent with what customers see and with the perceptions of crowding they report in satisfaction surveys.

The extensive deployment of APCs also allows TriMet to produce a stop level passenger census on a twice-yearly cycle. An example of passenger census information is shown in Table C-4 for inbound stops on a section of Route 8-NE 15th Ave. in weekday service. Average daily boarding and alighting statistics are reported, as are monthly lift deployments (from AVL vehicle monitoring data records). Passenger census information is also organized and reported by stop, summarizing passenger movements across all routes serving given stops.

Passenger census information is widely used throughout the agency. Within Operations the information is used primarily for stop planning, determining where amenities should be added, and identifying when and where customers with disabilities are connecting with the system. A recent large scale planning effort that focused on stop placement and stop consolidation also drew heavily on passenger census information. Passenger census information is also important in market research, as will be further discussed in the following section.

Conducting the passenger census using APC data has a number of advantages over the manual recording process that had been previously used. First, in the present system, data are current in comparison to the manual approach, which operated on a five-year cycle. Second, in the present system, data are comprehensive and precise in comparison to the old system, where each stop was sampled once in a six-month data collection period. Third, the new system replaces a manual process that was expensive, costing about $250,000 when it was last done in the 1990s.

Operator-keyed event data are a key feature of TriMet's AVL system, with 51 preprogrammed messages that operators can transmit to dispatchers by pressing selected numbers on the vehicle control head. Events include incidents and circumstances that are directly or indirectly related to customers' riding experience. Table C-5 shows a frequency breakdown for 16 event types recorded between June 3 and July 22, 2007. As previously discussed, events requiring maintenance or

Table C-4. TriMet passenger census, spring 2007 signup (weekday average).

Route No.	Route Description	Direction	Stop Location	Ons	Offs	Total	Monthly Lifts
8	8-NE 15th Ave	1	NE 15th & Killingsworth	93	22	115	23
8	8-NE 15th Ave	1	NE 15th & Sumner	37	5	42	1
8	8-NE 15th Ave	1	NE 15th & Alberta	254	105	359	32
8	8-NE 15th Ave	1	NE 15th & Going	50	8	58	15
8	8-NE 15th Ave	1	NE 15th & Prescott	68	11	79	3
8	8-NE 15th Ave	1	NE 15th & Mason	40	13	53	1
8	8-NE 15th Ave	1	NE 15th & Failing	31	9	40	2
8	8-NE 15th Ave	1	NE 15th & Fremont	106	49	155	21
8	8-NE 15th Ave	1	NE 15th & Siskiyou	21	6	27	0
8	8-NE 15th Ave	1	NE 15th & Knott	40	8	48	7
8	8-NE 15th Ave	1	NE 15th & Brazee	25	11	36	0
8	8-NE 15th Ave	1	NE 15th & Thompson	17	3	20	0
8	8-NE 15th Ave	1	NE 15th & Tillamook	34	20	54	29
8	8-NE 15th Ave	1	NE 15th & Weidler	48	97	145	15
8	8-NE 15th Ave	1	NE 15th & Halsey	27	52	79	7
8	8-NE 15th Ave	1	NE 16th & Multnomah	17	18	35	1
8	8-NE 15th Ave	1	NE Multnomah & 13th	122	178	300	20
8	8-NE 15th Ave	1	NE Multnomah & 11th	97	49	146	8
8	8-NE 15th Ave	1	NE Multnomah & 9th	80	29	109	16
8	8-NE 15th Ave	1	NE Multnomah & 7th	28	24	52	23
8	8-NE 15th Ave	1	NE Multnomah & Grand	24	39	63	6
8	8-NE 15th Ave	1	NE Multnomah & 3rd	22	13	35	3
8	8-NE 15th Ave	1	Rose Quarter Transit Center	241	169	410	68
8	8-NE 15th Ave	1	NW 3rd & Flanders	99	78	177	16
8	8-NE 15th Ave	1	NW 3rd & Couch	125	117	242	31
8	8-NE 15th Ave	1	SW 3rd between Oak & Stark	14	204	218	44
8	8-NE 15th Ave	1	SW 3rd & Yamhill	2	9	11	3
8	8-NE 15th Ave	1	SW 3rd & Madison	1	9	10	1

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Table C-5. Customer-oriented operator-keyed events, June–July 2007.

Event Type	Number of Events
Fare evasion	19269
Passup-overload	827
Mechanical problem-out of service	688
Skip stopping per dispatch	439
Route blocked	364
Lost/found item	349
Emergency-police	294
Sign/pole problem @ stop	282
Litter problem	231
Verbal passenger	225
Lift-rolling/passup	142
Shelter glass broken	114
No-injury accident	106
Emergency-medical	99
Shelter graffiti	92
Report hazard	76

repair are automatically forwarded as work requests, ensuring a more timely response to these problems.

Given that the event messages are operator initiated, it is likely that event counts understate the actual incidence of most of the phenomena that are covered in event records. Nevertheless, the event data provide important information in support of customer service and operations functions. A customer complaint about being passed up, for example, can be more readily resolved when event records show that the vehicle had been instructed to skip stops or was overloaded with passengers. The ability to document such facets of service delivery, along with the security enhancing features of the AVL system, help to explain why many operators favorably view the addition of this and other technologies.

Fare evasions are easily the most common operator-keyed events. Analysis of these event records can reveal patterns in time and space that can inform fare payment enforcement. With information such as that portrayed in Figure C-3, supervisors can assign fare inspectors to the "hot spots" where fare evasion is concentrated. While the map in Figure C-3 portrays fare evasion frequency at the traffic analysis zone level, the frequencies can also be portrayed at the stop level at finer geographic resolution.

Beyond facilitating the regular internal service delivery monitoring functions at TriMet, AVL and APC data also contribute to external reporting requirements and ad hoc evaluations. TriMet now samples the AVL-APC data archive for NTD reporting for bus and light rail service. The data validation and sampling procedures for the respective modes are described in Kimpel et al. (2003) and Strathman et al. (2005). Archived AVL data were used to evaluate the accuracy and precision of the real time vehicle arrival information produced by the agency's Transit Tracker system (Crout 2007). Changes in running time and running time variation have been evaluated following the implementation of signal priority technology at selected intersections in the city of Portland (Kimpel et al. 2005). And changes in passenger activity, running time, and running time variation have been evaluated following the relocation and consolidation of stops on selected bus routes (El-Geneidy et al. 2006).

Use of ITS Data in Market Research

TriMet maintains a comprehensive market research program. The most recent systemwide on-board survey of origins and destinations was completed in 2000. Since the 2000 survey, O-D data has been updated periodically on routes where major service changes have occurred. An annual attitude and awareness survey of riders and non-riders in the Portland region is conducted by telephone. Regional telephone surveys of customer satisfaction are also conducted periodically. Lastly, TriMet conducts an annual on-board survey to determine the mix and usage of fare instruments. The data from this survey are used to understand average pass use rates, employer pass usage, and who uses which method of fare payment.

TriMet's integration of ITS data with advanced market research practice is best illustrated in two research projects. The first used surveyed customer satisfaction data to construct satisfaction impact scores for twenty-seven service attributes. Customer perceptions of service attributes were then selectively compared to "reality" (represented by ITS data) to identify feasible improvements the agency could make that would have the largest customer satisfaction benefit. The second project drew on surveyed attitudinal data from riders and non-riders in the Portland region in a market segmentation analysis that sought to identify improvements that would have the greatest likelihood of retaining existing riders and attracting new riders.

TriMet's research on service attribute satisfaction is based on impact scores constructed from two pieces of customer survey information. The first piece is provided by the response to a question asking whether the customer had a problem related to a given attribute on his/her most recent trip. Those customers who respond "yes" are placed in one group and those who respond "no" are placed in a second group. The second piece of information is the customer's overall satisfaction rating (on a ten-point scale) of that attribute. For each attribute, a satisfaction impact score is calculated as the difference in mean satisfaction between the "yes" and "no" groups multiplied by the percentage of respondents in the "yes" group. Thus a high satisfaction impact score could be the result of a small percentage of customers experiencing a problem that has a large effect on their overall satisfaction (e.g., safety-related attributes) or, at the other extreme, a large percentage of customers experiencing a

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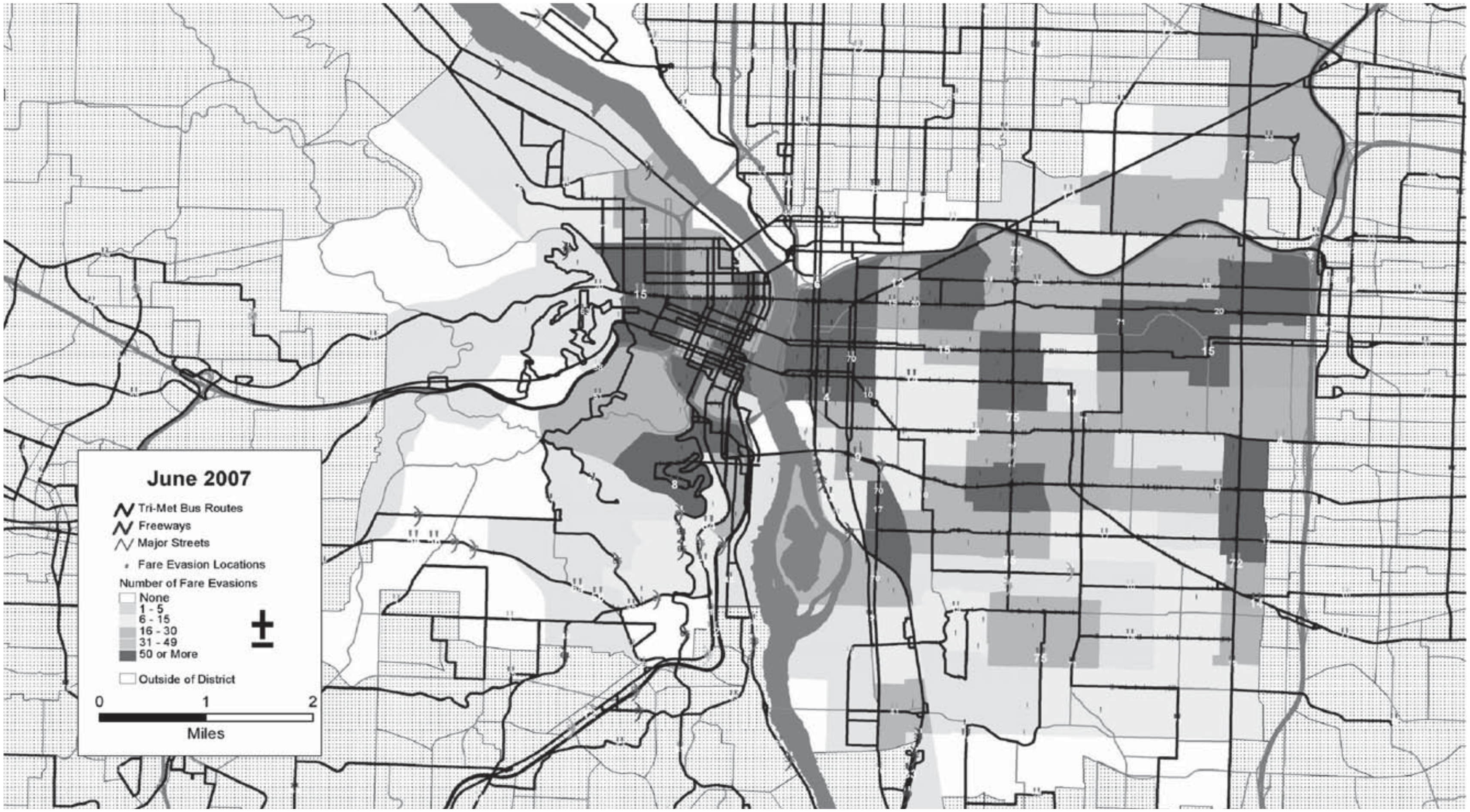

Figure C-3. Geographic incidence of operator-keyed fare evasion events, June 2007. (Supervisor District 3)

Leveraging ITS Data for Transit Market Research: A Practitioner's Guidebook

problem that has a modest effect on their satisfaction (e.g., availability of seats on a vehicle). The twenty-six attributes included in the customer satisfaction survey are presented in Figure C-4. The attributes can be grouped into categories related to service delivery, information provision, comfort, amenities, safety, and fare payment.

Among bus riders, TriMet found the satisfaction impact scores for twelve of the twenty-six attributes were statistically significant (see Figure C-5). The two largest satisfaction impact scores (and four of the top twelve) are associated with service delivery. Four comfort-related attributes are also among the top twelve, followed by three customer information-related attributes.

The impact scores help to identify the attributes that detract from customers' travel experience and can be expected to influence their future travel choices. While some factors (e.g., odors) are beyond a transit provider's control, most are not. With limited resources, managers cannot respond to all of the attributes that have an important influence on customer satisfaction, but the impact scores do help to prioritize actions. ITS data can facilitate this process in two ways. First, the data can help to identify where given problems are most acute. For example, combining schedule adherence data from AVL with APC passenger load data, one can ask, "Where are reliability problems affecting the greatest number of customers?" Also, using the same data, one can ask, "Is our worst overcrowding due to limited capacity or to poorly maintained headways?" Or, with AVL schedule adherence and APC boarding and alighting data, one can ask "What are our highest volume/longest wait stops lacking shelters?" In short,

Service Delivery
- Frequency/short wait times
- Reliable service/on schedule
- Vehicle not overcrowded
- Courteous/quick drivers
- Driver assistance/special needs
- Adequate capacity at park & ride lots

Information Provision
- Availability of real time information
- Delays explained/announced
- Clearly marked/visible stops
- Clear/timely announcements
- Availability of schedule information at stops
- Availability of schedules/maps

Comfort
- Absence of offensive odors
- Smoothness of rides/stops
- Physical condition of the vehicle
- Availability of seats on vehicle
- Comfort of seats on vehicle
- Cleanliness of vehicle exterior
- Cleanliness of vehicle interior
- Cleanliness of stops/stations
- Freedom from nuisance behavior

Amenities
- Availability of shelters

Safety
- Safety from crime at stops
- Safety from crime on vehicle

Fare Payment
- Affordability of trip
- Ease of paying fares

Figure C-4. Attributes included in TriMet's customer satisfaction impact analysis.

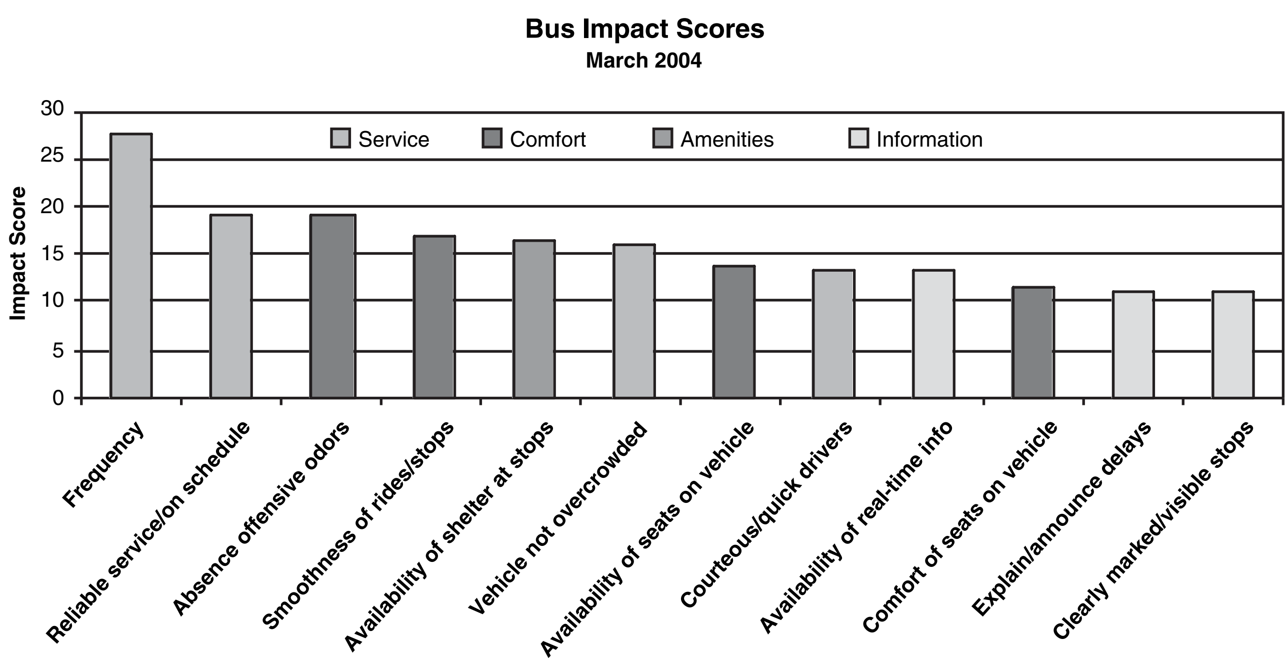

Figure C-5. Satisfaction impact scores from TriMet customer survey.

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ITS data can help managers achieve the greatest improvement in satisfaction with the limited resources at their disposal.

Second, ITS data can supplement customer satisfaction analysis over time through ongoing monitoring of service delivery, as well as by linking to replications of customer satisfaction surveys. For example, an earlier satisfaction impact study was completed in 2001, and the attributes with the five highest scores were, in order

- Frequency,
- Availability of a seat,
- Explain/announce delays,
- Reliable service/on schedule, and
- Availability of schedules and maps.

Comparing the 2001 and 2004 findings, it appears that reliability is an increasingly important satisfaction issue for customers. How does the change in satisfaction correspond to on-time performance trends over the period? Has service reliability deteriorated or has reliability become increasingly important to customers?

Further analysis of ITS data allowed TriMet market researchers to gain a better understanding of the linkages between service delivery trends and customer satisfaction. For example, while the trend in on-time performance over the period was essentially flat, examination of AVL headway data revealed that the incidence of bus bunching had increased. Bunching can affect customer perceptions in two ways. First, they are likely to view bus bunching as a reliability problem, independent of what on-time performance statistics say. Second, bus bunching removes effective capacity from a route and thus leads to an increase in the incidence of overcrowding, which was also observed in the 2004 study but not in 2001. Thus, in this instance, the resolution of two customer satisfaction problems depended on implementing operations control measures to better manage bus headways.

The ability to identify and respond to distinct travel market segments has been found to be a common feature of transit agencies that have built high ridership systems (TranSystems et al. 2007). These agencies strategically target marketing and customer information, fare options, and service improvements, ensuring that resources are invested where they will produce maximum ridership returns. ITS data offers a cost-effective, timely, and comprehensive means of monitoring customer responses to targeted marketing investments.

Market segmentation research in the transit industry is evolving from the days when travelers were distinguished by age, sex, income and car ownership to more sophisticated approaches that supplement the traditional metrics with information on attitudes and preferences. An example of the new approach is a market segmentation study of TriMet's service area by Gilmore Research Group, first conducted in 1993, and updated in 1998 and 2004. In the 2004 study, a population survey was conducted by telephone with over 2,600 service area residents. Along with demographic and travel activity information, the survey recovered scaled responses to a variety of questions related to travel preferences, the benefits associated with transit as a travel option, TriMet's performance as the region's transit provider, and general conditions in the region.

The first step in the analysis of the survey data employed a factor analysis of scaled responses to the battery of attitudinal questions. The factor analysis identified five underlying principal components organized around the responses to eighteen of the survey's attitudinal questions. Next, cluster analysis was performed on the eighteen attitudinal question responses. This analysis yielded the five cluster groups, or market segments, presented in Figure C-6. Several things should be noted about the characteristics associated with these market segments. First, with respect to travel mode, respondents were defined to be transit riders if they reported having taken more than two trips on the system in the past month. Second, while the clusters were generated from attitudinal data, distinctions between segments related to income, demography, and length of residence sometimes emerged.

The largest market segment cluster, labeled "Transit is a Lifestyle Choice," represents over one-third of the survey respondents, 43% of transit riders, and 28% of non-riders. Compared to other segments, members of this group tend to be more supportive of transit (particularly bus) as a travel option and hold more favorable opinions about TriMet's performance as a transit provider. They view transit as a convenient and economical means of travel, and recognize transit's social and environmental contributions to the region's livability. They tend to be newer to the Portland area, better educated, and more likely to reside in urban neighborhoods. Given these defining characteristics, TriMet market researchers concluded that the strategy with the greatest likelihood of retaining current transit riders and attracting non-riders from this segment should focus on improving service.

The second largest market segment is labeled "I'm not Comfortable Riding the Bus." This group includes over one-quarter of the sample and more than one-fifth of the transit riders surveyed. Its disproportionately female members acknowledge transit's benefits, but also express discomfort with being around strangers and concern about their personal safety. Retention of existing riders will likely depend on providing enhanced security measures, and making other changes that would reduce their waiting time at stops and make their waits more amenable. Attraction of non-riders will further depend on effectively communicating the improvements that are made.

Market Segment Label	Composition	Demographic-Attitudinal Characteristics	Attraction-Retention Strategy
"Transit is a Lifestyle Choice"	43% of Riders 28% of Non-riders 35% of Sample	• Pro-bus & pro-TriMet • See riding as convenient, economical, & good for Portland's livability • Newer to the area, well educated, & live in urban neighborhoods	• Likely to respond to service improvements
"I Use Transit When it Makes Sense"	18% of Riders 14% of Non-riders 16% of Sample	• Demographics similar to the region's • No strong attitudinal barriers toward using transit • Don't have a compelling reason to use transit more often	• Likely to respond to promotional marketing & service improvements
"Riding the Bus Saves Money for My Family"	10% of Riders 10% of Non-riders 10% of Sample	• Predominantly male & more ethnically diverse • More children at home • Transit is "a way to get around" • Places low value on transit's environmental & social benefits	• Likely to respond to service improvements, new service, & more stop amenities
"I'm not Comfortable Riding the Bus"	22% of Riders 29% of Non-riders 26% of Sample	• Predominantly female • Not comfortable around strangers • Concerned about personal safety • Recognizes transit's environmental & social benefits	• Likely to respond to security measures, more stop amenities, and service improvements that reduce wait time
"There's no Way I'm Getting on a Bus!"	7% of Riders 19% of Non-riders 13% of Sample	• Married, homeowner, high income, longer term resident • Anti-transit & anti-TriMet • If they ever ride, only use light rail • Always prefer to drive, even in rush hour traffic	• None

Figure C-6. Portland region's transit market segments in 2004.

If there is such a person as the "median citizen" in the Portland region, he/she would be a member of the third largest market segment, labeled "I Use Transit When it Makes Sense." The demographics of this group are close to the regional averages. They are not disinclined to use transit, but neither are they so inclined. Promoting the advantages of transit use coupled with service improvements likely offers the greatest prospect of providing this group a compelling reason to choose transit over other modes.

The fourth largest market segment, labeled "There's no Way I'm Getting on a Bus," associates transit with everything they see going wrong in the Portland region, and there is likely to be little that can be done that would sway members of this cluster from that opinion. They are relatively well off, have lived in the area the longest, and are convinced that auto is the only way for them to travel.

The smallest market segment, labeled "Riding the Bus Saves Money for My Family," views transit as the most economical (and, for many, the only) option for traveling in the region. Improvements in comfort and speed are changes that would provide the most likely means of building ridership in this segment.

Defining market segments provided TriMet with a basis for developing strategies to grow transit ridership in the Portland region in a cost effective way. The actual implementation of strategies tailored to each market segment also depended on knowing where each market segment was geographically concentrated. Sampled market segments were inferred to zip code populations and mapped in relation to the transit system. Figure C-7 shows where the "Transit is a Lifestyle Choice" market segment is concentrated. Service improvements that target this group should be directed to routes serving areas where the group's concentration is highest.

The effectiveness of the service improvements can be monitored by relating APC boarding and alighting data from stops in the subject areas to overall passenger trends. It would not be surprising to observe ridership growing faster where the service improvements are implemented. Rather, the effectiveness of the market segmentation analysis should be based on the extent to which the observed rate of ridership increase in the target areas exceeds a benchmark rate representing the average system level ridership response to a change in the level of service.

In addition to the two research projects reviewed above, market research staff at TriMet draw on ITS data to facilitate their ongoing practices. APC ridership data provide the greatest utility, and serve in the following applications:

- Stop level boardings and alightings are used for on-street intercept surveys to determine the best times to survey, and when or where more than one surveyor is needed.
- Route level ridership data are used for on-board intercept surveys to determine sampling rates, to determine how many surveys to print, and to determine weighting factors for expanding sample responses to population totals.
- Ridership data are analyzed to assess the effects of changes to the system, including fare increases and service hours.
- Survey responses on satisfaction with "overcrowding" are compared with passenger load data to identify specific

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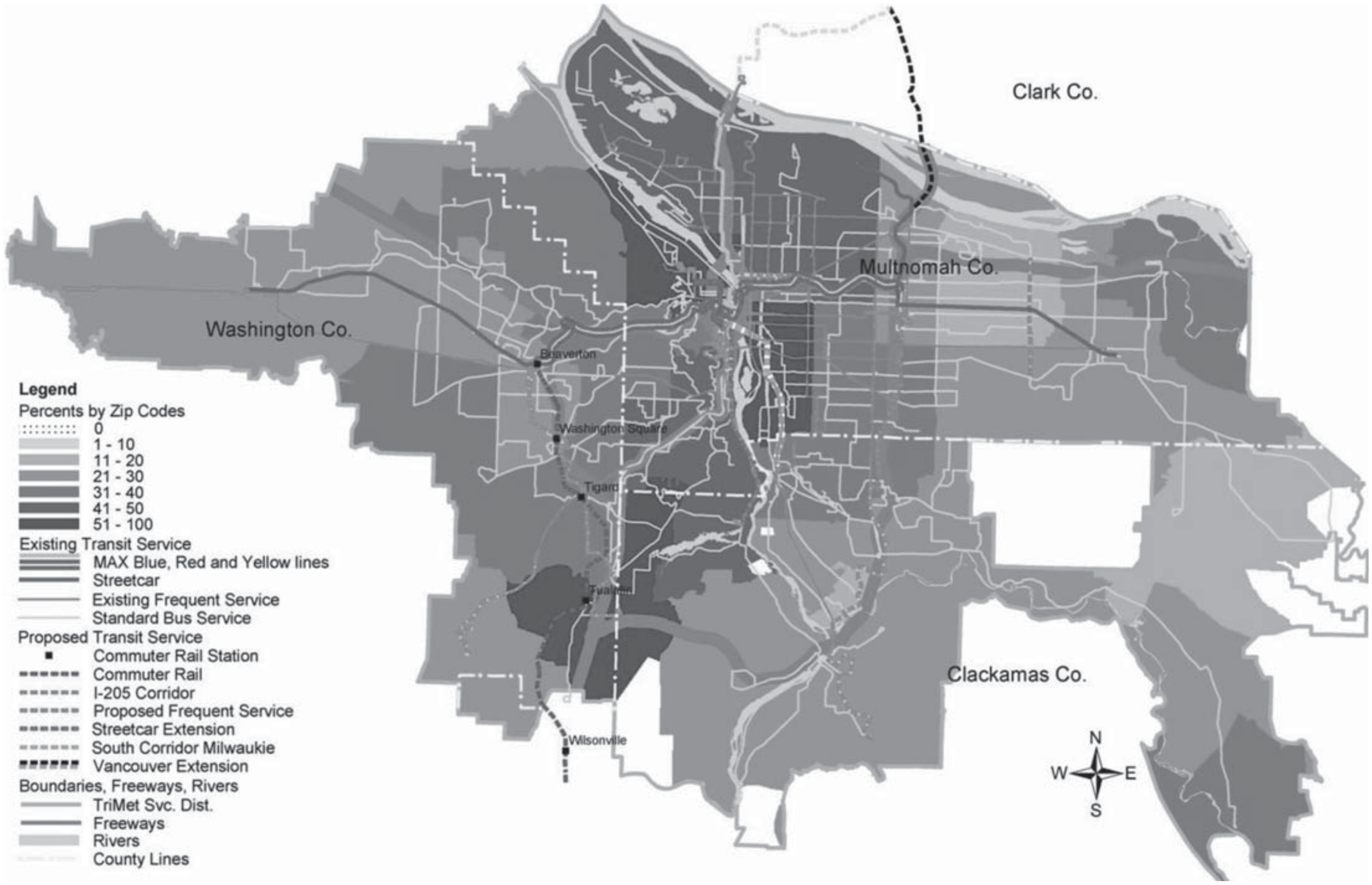

Figure C-7. Spatial distribution of the "Transit is a Lifestyle Choice" cluster group.

circumstances where high passenger loads are affecting customer satisfaction.

- Survey vendors draw on stop and route passenger data to gain a better understanding of the dynamics of the system's operations.

In one instance, APC data have substituted for traditional practice. Prior to 2004, monthly ridership estimates were determined from an annual passenger fare survey, which provided the mix and usage of fare instruments, along with monthly fare revenue receipts by type of fare (e.g., cash, pass). Changes in fares and fare instruments were increasingly complicating the estimates, and the traditional approach was replaced by a sampling and estimation procedure that drew on archived APC data.

Web and phone data are used by market research staff in assessing the effectiveness of communications with customers and in evaluating customer communication with TriMet. Page hits on the Web proxy the visibility of messages to customers. With a major reconstruction of the downtown transit mall currently underway, a low number of hits on the construction and service information links would indicate that more promotion would be needed to increase the visibility of this information.

Market research staff have conducted Web satisfaction surveys. Pages or links with high hits that draw low survey satisfaction responses would be prime candidates for redesign. The logs from the Trip Planner and Transit Tracker links could be compared to demographic data from the origin-destination survey to identify where communication gaps exist between the agency and customer groups. These gaps could be targeted for additional promotion of available information technology options or could be designated as areas that need traditional printed materials.

Issues, Observations, and Challenges

There is substantial evidence of a progressive evolution in TriMet's 10+ years experience with the recovery, archiving, and analysis of ITS data. It is noteworthy that when TriMet's AVL system was deployed, vendor-developed reporting software did not exist. Staff developed the reports described in this case study from structured queries of the event history tables. However, as the other case studies have demonstrated, such data query skills proved essential in capturing the full value of ITS data.

In realizing value from ITS data, TriMet has benefited from staff resources that compare favorably to those at the CTA and Madison Metro Transit. An institution-level employment measure does not necessarily reflect IT and research staff levels; it does offer one explanation for why TriMet has experienced success in utilizing AVL and APC data for market research and planning while other transit properties have often struggled to advance beyond standardized reports.

In the course of our interviews, we asked TriMet staff to reflect on issues, challenges, and lessons learned from working with ITS data. The case study concludes with a summary of staff observations.

Market Research

- Market Research staff operate in a statistical package for the social sciences (SPSS) environment. Data cannot be weighted within GIS for expansion, so selected fields have to be first exported to Excel, manually weighted, and then imported into a GIS. The process is time consuming and cumbersome.
- Market Research staff use SPSS; Operations staff use SAS; and the ITS data are in Oracle tables. The software environment supporting data analysis is not very user friendly.
- Metadata describing the contents of the ITS data archive are lacking. There are only a few people who fully understand the data archive. Understanding and finding the exact data one needs requires multiple requests, is time consuming and uses two people's time instead of one.
- Survey data could be geocoded and placed in the data archive so that it would link to ITS data and be available for agency-wide use. However, there is a desire in market research to maintain control over the availability of survey data to avoid situations where the data are misunderstood or misinterpreted.

Operations/Service Planning/Scheduling

- Errors in data or interpretation can ruin trust.
- It has been a challenge aligning information from ITS data with what top management needs to make better decisions.
- When managers are used to such detailed information, the time and effort that it takes to create, maintain, and analyze the data begins to lose value.
- Data matching is essential; AVL and APC data are virtually useless if they cannot be matched to the schedules. ITS vendors have very limited capabilities in this area. The data matching process is not simple; it must be fully automated to handle the large volume of data records and it must provide sufficient feedback to allow "malfunctions" in the data to be detected. The process must be actively monitored because there are always new twists in how vehicles are operated, including reroutes, operations control actions, and operator misbehavior. TriMet's data matching practices began prior to the deployment of AVL, when odometer and time-stamped APC data were matched to schedules, and have evolved to the current heuristic programs that incorporate a variety of issues discovered over time. Fundamentally, successful data matching requires active collaboration between programmers and staff familiar with scheduling data practices.
- Post processing of the raw data is an important step; there are a number of anomalies in the raw data. But keep the raw data because some applications need it.
- Staff responsible for post processing the AVL, APC and event data have been a valuable resource to other staff in their efforts to analyze ITS data.
- Be sure to get detailed documentation from vendors. For example, staff was told that a data record was created when the bus door opens, but discovered 10 years later that a record is created when the bus enters the GPS stop circle.
- Allowing unlimited access to ITS microdata can lead to misuse and misinterpretation. This advocates for granting wide access to summary data and restricted access to individual data records.

Information Technology and GIS

- The TriMet system generates 36 million data records every three months. The data are complex in that both spatial and temporal features must relate to each other. A relational database management system (RDBMS) provides the only way to manage this data in an effective way so staff can answer complex questions that cross department boundaries.
- There is a tendency to have a single-minded focus in specifying and deploying ITS technologies in transit. It is important to engage IT staff early in the process to ensure compatibility with the enterprise data model and to allow for applications beyond the designed use of the technology.
- Metadata for the data model and data tables is usually not created because it is very time intensive. Consequently, most analysts don't fully know what data are available in the enterprise system and cannot take full advantage of it. A good technical writer is needed to create data documentation.
- With emerging applications like Google Transit, it is becoming increasingly important for transit data to be publicly accessible in a standard format. Without an Enterprise Data Environment, this can be difficult and complicated.
- Larger transit properties need a database administrator (DBA) to manage the enterprise data system. Smaller properties also have enterprise data system management needs, which could potentially be met by contracting out or pooling resources among properties to hire a single DBA.
- An enterprise RDBMS is needed to fully support GIS applications using ITS data.

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Tom Strader, Senior Research Analyst

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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