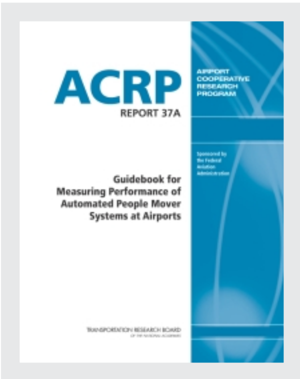


Guidebook for Measuring Performance of Automated People Mover Systems at Airports

DETAILS

125 pages | | PAPERBACK
ISBN 978-0-309-21389-9 | DOI 10.17226/14606

AUTHORS

Transportation Research Board

AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 37A

Guidebook for Measuring Performance of Automated People Mover Systems at Airports

LEA+ELLIOTT, INC.
Dulles, VA

WITH

WATCHUNG TRANSPORTATION, LLC
Westfield, NJ

Subscriber Categories
Aviation

Research sponsored by the Federal Aviation Administration

TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
2012
www.TRB.org

AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), and the Air Transport Association (ATA) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

ACRP REPORT 37A

Project 03-07
ISSN 1935-9802
ISBN 978-0-309-21389-9
Library of Congress Control Number 2012931873

Published reports of the

AIRPORT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

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

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

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

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

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

www.national-academies.org

C O O P E R A T I V E   R E S E A R C H   P R O G R A M S

CRP STAFF FOR ACRP REPORT 37A

Christopher W. Jenks, *Director, Cooperative Research Programs*
Crawford F. Jencks, *Deputy Director, Cooperative Research Programs*
Michael R. Salamone, *ACRP Manager*
Lawrence D. Goldstein, *Senior Program Officer*
Tiana Barnes, *Senior Program Assistant*
Eileen P. Delaney, *Director of Publications*
Doug English, *Editor*

ACRP PROJECT 03-07 PANEL
Field of Policy and Planning

John Kapala, *Hartsfield–Jackson Atlanta International Airport, College Park, GA*
William H. Leder, *Michigan Technological University, Houghton, MI*
Tomas Rivera, *Dallas–Fort Worth International Airport, DFW Airport, TX*
Michael Shumack, *Greater Orlando Aviation Authority, Orlando, FL*
Gerald K. Winters, *Markham, ON*
John G. Bell, *FTA Liaison*
M. Ashraf Jan, *FAA Liaison*
Gil Neumann, *FAA Liaison*
Jennifer A. Rosales, *TRB Liaison*

AUTHOR ACKNOWLEDGMENTS

The research reported herein was performed under ACRP Project 03-07, "A Guidebook for Measuring Performance of Automated People Mover Systems at Airports." Lea+Elliott, Inc., was the contractor for this study, with Watchung Transportation, LLC, as a subcontractor.

Christopher M. Gambla, Senior Associate of Lea+Elliott, was the Project Manager and Principal Investigator. Jack Norton, President of Lea+Elliott, was the Principal-In-Charge. Other contributors to this report were Doug Draper, CAD Specialist of Lea+Elliott; Craig W. Elliott, Project Engineer of Lea+Elliott; Dennis M. Elliott, Principal of Lea+Elliott (retired); Jack E. Joy, Associate Principal of Lea+Elliott; Charlie Martin, Principal of Lea+Elliott (retired); Sophia Mucino, Technical Documentation Specialist of Lea+Elliott; Curtis Newton, Manager of Engineering Projects of Lea+Elliott; Melinda Ring, Manager of Planning Projects of Lea+Elliott; and Rongfang (Rachel) Liu, Principal of Watchung Transportation.

The research team would like to express its gratitude to the members of the project panel for their support and insightful comments throughout this research project. The research team would also like to thank the many airport staff who took the time to accommodate tours for project staff; share their insights, experience, and opinions with the research team through survey participation; and respond to follow-up inquiries.

FOREWORD

By Lawrence D. Goldstein
Staff Officer
Transportation Research Board

ACRP Report 37A is a guidebook for measuring performance of automated people mover (APM) systems at airports. This report, directed at airport owners and operators as well as owners and operators of APM systems, identifies, defines, and demonstrates application of a broad range of performance measures encompassing service availability, safety, operations and maintenance expense, capacity utilization, user satisfaction, and reliability. The guidebook also identifies the data required to implement these performance measures, helping airport APM operators assess and improve performance over time, compare alternative APM systems, and plan and develop future APM systems. This report includes an appendix that documents the underlying historical research and describes the survey instrument and responses that provided information used to formulate specific performance measures. Also included in this volume, and available electronically on the *ACRP Report 37A* summary web page at http://www.trb.org/Main/Blurbs/166387.aspx, is a set of forms for periodically compiling the necessary data for input into the overall performance measurement process. Also available via the *ACRP Report 37A* summary web page is an interactive Excel model containing spreadsheets that can be used to track and calculate system-wide performance and service characteristics.

This report is a companion to *ACRP Report 37: Guidebook for Planning and Implementing Automated People Mover Systems at Airports*. Together, these two volumes provide a comprehensive planning, development, operating and maintenance, and system performance manual that takes the user from initial planning and development steps through implementation, operation and maintenance, and overall performance monitoring and evaluation.

Airport APM owners and operators, as well as airport owners, will find *ACRP Report 37A* of special interest. Typically, these parties view daily, monthly, and yearly performance measures of their APM systems in a framework within which only the system itself controls. Under this approach, delays that result from external causes, such as weather, passengers (holding doors, injuries/events on board trains, etc.), and other similar incidents beyond the control of the system are excluded from overall system evaluation. Excluding uncontrolled events artificially improves the performance of the APM on paper but does not represent what passengers actually experience when using the system. A good example is a significant snow event, where the airport APM may have shut down for half the operating day. Under current procedures, system availability would be reported as 100% for the entire day (assuming there were no delays during the time the system was operating) because the weather event was beyond the control of the system. A passenger, however, would not have reached the same conclusion. In contrast to this limited approach to performance evaluation, this report provides a comprehensive set of measures that describe the actual performance of airport APMs in the context of all events, regardless of the reason for those events. What is measured by applying these factors is the performance of the APM system from the passengers' perspective, which ultimately is who the APM serves.

Applicability across a broad spectrum of airport systems requires flexibility in the actual measurement parameters. An example of how this flexibility is incorporated into the guidebook is the proposed Service Availability measure. For this performance measure, three options are provided, allowing the Service Availability metric to be calculated using the method best suited to a particular airport APM system. In addition, because the seven performance measures identified in the guidebook, by themselves, do not provide the whole story when comparing the performance of one airport APM to another, the guidebook identifies six system descriptive characteristics and five service descriptive characteristics to be reported along with the performance measures. These additional characteristics provide a context for the specific measures where there are differences caused by APM configuration, technology, or other design or operating characteristics.

Taken together, *ACRP Reports 37* and *37A* serve as a comprehensive guide for use by the airport industry to provide a safe and efficient APM system as a function of specific airport design, capacity requirements, and operational characteristics. Once implemented, the performance measures presented in this guide can be used to oversee and improve system performance in response to both industry and user needs and requirements.

CONTENTS

SUMMARY

Guidebook for Measuring Performance of Automated People Mover Systems at Airports

This guidebook presents the research and findings for ACRP Project 03-07, "A Guidebook for Measuring Performance of Automated People Mover Systems at Airports." The objective of this project was to provide a user-friendly guidebook for measuring performance of automated people mover (APM) systems at airports.

The guidebook is a continuation of *ACRP Report 37: Guidebook for Planning and Implementing Automated People Mover Systems at Airports,* transitioning the user from the process of airport APM planning, design, and implementation to the ongoing operations, maintenance, and performance measurement of these systems.

Specifically, the guidebook identifies a set of performance measures and associated data requirements for airport APM operators to assess and improve performance, compare APM systems, and plan and design future APM systems. The performance measures address the efficiency, effectiveness, and quality of APM systems at airports, particularly focusing on impacts on APM passengers and on airport performance. In this last regard, the user will see that the guidebook performance measures generally depart from the traditional industry method of allowing for grace time and for the exclusion of downtime for events not attributable to the APM system and instead require that all downtime, durations of which the customer experiences, be reflected in the measure.

The following set of airport APM performance measures are the result of the work performed on the project and are described in detail within the guidebook:

1. Service Availability
2. Safety Incidents per 1,000 Vehicle Service Miles
3. Operations and Maintenance (O&M) Expense per Vehicle Service Mile
4. Actual and Scheduled Capacity (Peak Versus All Other)
5. Passenger Satisfaction
6. Missed Stations per 1,000 Station Stops
7. Unintended Stops per 1,000 Interstations

The guidebook also identifies and defines the airport APM system descriptive characteristics required when reporting the performance measures so as to provide context to the measures when they are compared among two or more airport APM systems. The descriptive characteristics are:

A. System Descriptive Characteristics
   1. Single Lane Feet of Guideway, Mainline
   2. Single Lane Feet of Guideway, Other
   3. Routes Operated in Maximum Service

4. Trip Time in Maximum Service
5. Stations
6. Vehicles in Total Fleet

and

B. Service Descriptive Characteristics
1. Passenger Trips
2. Vehicle Service Miles
3. Vehicles Operated in Maximum Service
4. Vehicles Available for Maximum Service
5. Headway in Maximum Service

Along with the performance measures and system and service descriptive characteristics, the guidebook provides the airport APM owner/operator with the necessary forms and spreadsheet tools to assist in implementing the guidance provided in this document. Exhibit A

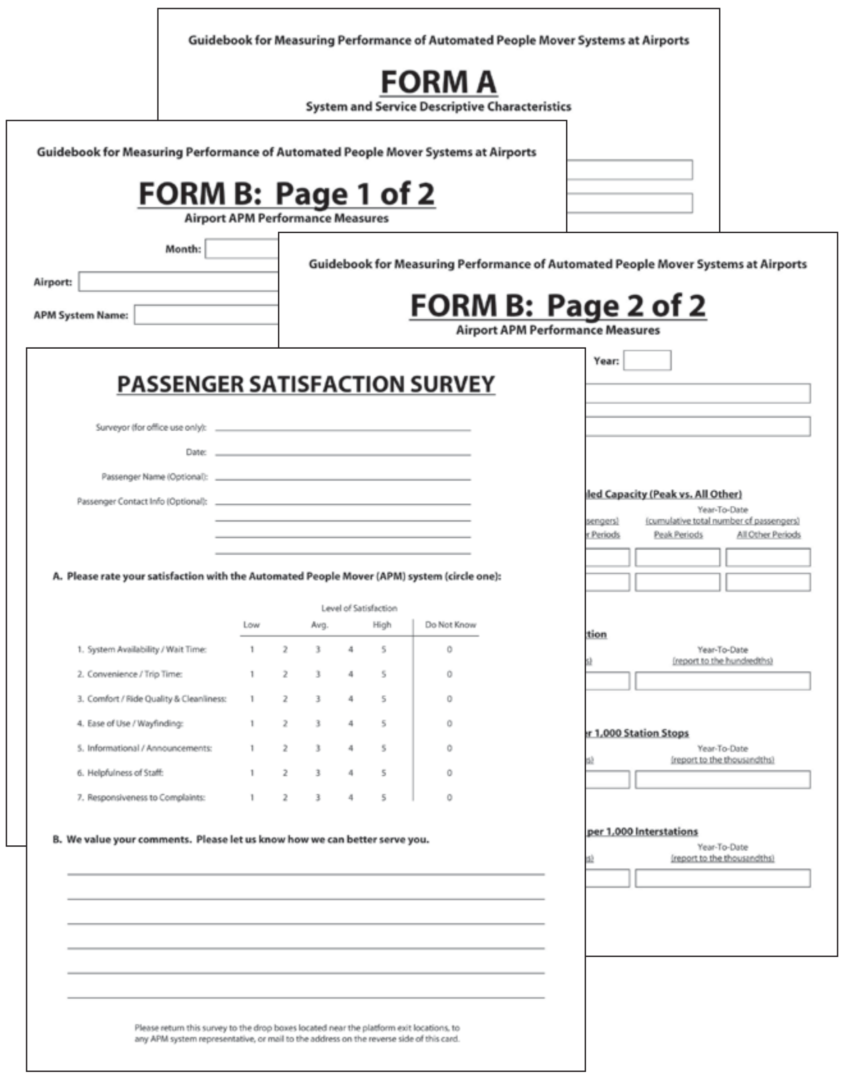


Figure 1. Image of forms provided in Exhibit A.

of the guidebook provides Form A (System and Service Descriptive Characteristics), Form B (Airport APM Performance Measures), and the Passenger Satisfaction Survey, which can be used to collect and report performance measurement data within organizations or the industry.

A Microsoft Excel workbook containing several spreadsheets that can be used to track and calculate the performance measures and system and service characteristics is provided with the guidebook as a download from the summary page for *ACRP Report 37A* at http://www.trb.org/Main/Blurbs/166387.aspx, with all of the formulas in the guidebook programmed into the spreadsheets for easy implementation. The forms in Exhibit A are also provided in electronic form at this website to facilitate electronic completion and compilation of data.

This guidebook also contains Appendix A with the underlying historical research, survey plan and instrument, survey response data and associated analyses, and other material that assisted in forming the basis for the guidebook.

The guidebook, forms, tools, and supporting material provide a comprehensive approach to measuring performance of APM systems at airports.

CHAPTER 1

Background

From its beginnings in the early 1970s, the airport automated people mover (APM) industry today is well established. As of 2010, there were 44 APM systems operating at airports worldwide. Performance measurement of airport APM systems has generally been focused on service availability and its component subparts. However, unlike in other industries, a common set of metrics to measure and compare performance of airport APM systems does not exist. The reasons for this include that:

- There is no central authority over airport APM systems that requires performance reporting or performance visibility to the general public, such as exists for most public transit agencies in the United States [i.e., because airport APM systems typically are not funded with federal dollars, they are generally not subject to the performance reporting requirements established by Congress through 49 United States Code (USC) 5335 and the National Transit Database]. A by-product of federal funding involvement in the commercial aviation and highway industries has been the creation of common performance measures that are tracked, reported, compared, and publicly disclosed.
- Airport APMs are largely operated and/or maintained under contract to a private services provider, often the system supplier. These contracts typically compensate the provider based on performance, the terms of which are incorporated as part of the contract. The performance measure or measures made part of these contracts generally include at least service availability, but the ultimate rules, exclusions, and method(s) of calculating these measures are subject to negotiation with the owner. Therefore, the service availability performance metric can vary dramatically from one system to the next.
- Airport APM systems vary greatly in their sizes, configurations, technologies, maintenance provisions, ages, and operating environments, making it more challenging to specifically identify a common set of measures applicable to all.

Because a common set of performance measures within the airport APM industry does not exist, the call for research on the topic was initiated by ACRP through this project.

1.1 Research Approach

Research on the project was undertaken using a stepwise approach, with assistance from the larger airport and urban APM community, and under the oversight of a panel composed of members from the airport APM industry.

The project team began by reviewing pertinent literature on performance measurement, both in general and as specifically applied to APM systems at airports worldwide. The review identified best practices as well as the processes undertaken to develop and implement performance measurement programs for APM systems at airports. The project scope was limited to airport APMs in North America. The review concluded with a summary of the theory and practice of performance measurement in other relevant transportation and service industries, the relevant aspects of those performance measurement practices, the performance measures used, and their potential usefulness to airport APM systems.

The next step of the research involved developing a plan for a survey to investigate the current practice of performance measurement by APM systems at airports. The plan included details on gathering data from visits to select airport and urban APM system sites in North America, a copy of the survey instruments, a list of the airport and non-airport APM properties to be surveyed, and the areas that the survey addressed, which included the characteristics of APM systems, the performance measures used, the data collection practices associated with the performance measures, performance data for the most recent year, and suggestions for improving data collection and performance measurement practices.

The inclusion of urban (non-airport) APM systems in the survey was required as part of the survey plan, and the goal was to obtain at least 10 responses from the survey (at least seven airport APM responses and at least three non-airport APM responses). Upon approval of the survey plan by the panel, the project team implemented the survey across approximately 30 airport and non-airport APM properties in North America, obtaining an almost 50% survey return rate. The survey results were compiled and subsequently analyzed, identifying similarities and differences in defining performance measures and data among APM systems.

Following the analysis of the survey results, the project team assessed the feasibility of developing performance measures that could be used to assess and compare APM systems at airports, considering the differences among such systems. An interim report was prepared that documented the results of the work up to that point, and the project team met with the panel to discuss the findings.

For various reasons, including the significant differences among airport APM systems, the meeting involved a vigorous discussion about the feasibility of developing a common set of performance measures to be used to compare airport APM systems, with some believing it was possible and others believing it was not.

The project team moved forward with developing the performance measures to be part of the guidebook, concise definitions for each measure, the data needed to calculate each performance measure, and the required data collection and reporting techniques and associated resource requirements. This information was placed into the draft guidebook, iterations of which were reviewed by the panel. Several rounds of comments were provided by the panel, which were considered and almost universally incorporated into the guidebook by the project team. These comments from panel members who are part of the airport APM industry, the research undertaken by the project team, the experience of the project team in the industry, and the knowledge gained from responses by the airport APM properties have resulted in a collaborative, comprehensive guidebook for measuring performance of APM systems at airports.

This report begins with a summary of the guidebook, this chapter, which provides the background on the project and research approach, and follows with:

Chapter 2: Introduction
Chapter 3: Transitioning from APM Planning and Implementation to APM Operations and Maintenance
Chapter 4: Performance Measurement of APM Systems at Airports: The Current Situation
Chapter 5: Performance Measures for APM Systems at Airports: Recommended Approach
Chapter 6: Other Airport APM System Performance Measures
Chapter 7: Implementing an Airport APM Performance Measures Program

The guidebook also includes Exhibit A, which contains the forms to be used to report the airport APM performance measures and descriptive characteristics on a monthly basis, as well as the survey to be used to gather data for the Passenger Satisfaction performance measure.

The forms provided in Exhibit A are available for download from the summary page for *ACRP Report 37A* at http://www.trb.org/Main/Blurbs/166387.aspx. The electronic version of these forms will provide for easier dissemination and tracking. A Microsoft Excel workbook file of numerous spreadsheets that will aid the user in tracking and calculating the performance measures and descriptive characteristics described in the guidebook is also available for download from the *ACRP Report 37A* summary page.

CHAPTER 2

Introduction

An automated people mover is a transportation system with fully automated operations that features vehicles on guideways with an exclusive right of way. About 44 APM systems are operating at airports worldwide. APM systems are implemented at airports to facilitate passenger and employee movement, generally within the confines of the airport. They typically operate from passenger check-in areas to airplane gates and between gates, allowing more people to move more quickly over longer distances, connecting large, often dispersed airline terminals. More recently, APM systems have been designed to connect airport terminals with parking facilities, car rental services, regional transportation services, hotels, and other related employment and activity centers.

APMs are vital to the operation of many airports in that they provide the fastest and sometimes the only means to travel within the airport. Serious problems arise when an airport APM system does not operate well or stops entirely. Given the critical importance of APM systems in the operations of airports, it is essential for APM operators and decision makers to evaluate and manage their systems using a representative complement of performance measures.

Today, owners/operators of airport APMs routinely collect system data and develop performance measures to monitor and manage their performance. The measures typically address service reliability, availability, and maintainability as well as operations and maintenance contract compliance. Currently, however, there are no performance measures or data-collection practices common to all airport APMs, and research has been needed to develop meaningful tools for measuring and comparing their performance. A key challenge to conducting meaningful comparisons is that no two airport APM systems are identical. For example, systems have different sizes, configurations, technologies, maintenance provisions, ages, and operating environments. In addition, performance comparisons must be based on comparable performance measures using comparable data.

2.1 Purpose

The objective of ACRP Project 03-07 was to develop a user-friendly guidebook for measuring performance of APM systems at airports. This guidebook identifies a set of performance measures and associated data requirements for airport APM operators to assess and improve performance, compare APM systems, and plan and design future APM systems. The performance measures address the efficiency, effectiveness, and quality of APM systems at airports.

2.2 Who Should Use This Guidebook?

This guidebook was developed for use by airport APM system owners and operators having the responsibility for the recurring operations and maintenance of the APM, as well those with the responsibility for future expansion of the existing APM system or for a separate APM at the same airport. It is assumed that the user of this guidebook will be well versed in the operations and maintenance of airport APM systems, their capabilities, and the details concerning performance measurement of these systems. Those responsible for collecting, tracking, calculating, and reporting performance measures will also benefit to a great extent from the material in this guidebook.

2.3 How to Use This Guidebook

This guidebook is generally targeted for the audiences described in Section 2.2. Those responsible for contracting operations and maintenance (O&M) services for an airport APM system, planning the expansion of an existing system, or planning a new APM system will benefit from the content in Chapter 3 (Transitioning from APM Planning and Implementation to APM Operations and Maintenance); Chapter 4 (Performance Measurement of APM Systems at Airports: The Current Situation); Chapter 5 (Performance Measures for APM Systems at Airports: Recommended Approach); Chapter 6, Section 6.2 (Measures for Planning and Designing Airport APM Systems); and Chapter 7 (Implementing an Airport APM Performance Measures Program). These individuals should familiarize themselves with this content to be prepared to appropriately structure O&M contracts requiring performance measures to be tied to compensation and to understand how the measures that will be tracked and reported during the O&M phase of an airport APM system will affect and drive the planning and design of future expansions or new systems at the airport.

Those individuals who are responsible for collecting, tracking, calculating, and reporting the airport APM performance measures will benefit from the content in Chapter 5 (Performance Measures for APM Systems at Airports: Recommended Approach); Chapter 6, Section 6.1 (Internal Measures for Assessing and Improving Performance of Airport APM Systems); and Chapter 7 (Implementing an Airport APM Performance Measures Program). These individuals will need to be intricately familiar with the details of the content in these chapters since the mechanics of the performance measures are contained therein and since they will be the ones responsible for the accurate calculation and reporting of the measures.

2.4 Other ACRP Reports

ACRP carries out applied research on problems that are shared by airport operating agencies. It undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. ACRP produces a series of research reports such as this guidebook for use by airport operators, government agencies, and other interested parties to disseminate findings.

This guidebook is a follow-on document to *ACRP Report 37: Guidebook for Planning and Implementing Automated People Mover Systems at Airports.* Other ACRP research reports and projects that deal with performance measurement are:

ACRP Report 19: Developing an Airport Performance Measurement System;

ACRP Report 19A: Resource Guide to Airport Performance Indicators; and

ACRP Project 02-28, "Airport Sustainability Practices: Tools for Evaluating, Measuring, and Implementing" (in process).

CHAPTER 3

Transitioning from APM Planning and Implementation to APM Operations and Maintenance

ACRP Project 03-06 produced *ACRP Report 37: Guidebook for Planning and Implementing Automated People Mover Systems at Airports.* ACRP Project 03-07 provides this report as a companion to *ACRP Report 37.* Taken together, these two guidebooks provide airport staff and other appropriate stakeholders a recommended pathway forward that spans the range from initial APM conceptualization to measuring and maximizing the efficiency of the actual day-to-day operation and maintenance of the APM system.

The reader is encouraged to consult *ACRP Report 37*—particularly Chapter 10, APM System Procurement and Chapter 11, Operations and Maintenance. These chapters offer a high-level overview of moving from the planning of an APM system to its actual procurement, as well as options for its ongoing operation and maintenance. Chapter 3 herein reiterates some of the highlights of Chapters 10 and 11 of the other report, elaborates on related aspects, and offers recent developments in procuring O&M services that have occurred subsequent to the research and publication of *ACRP Report 37.*

Chapter 3 discusses the contractual aspects of transitioning from planning and implementing an APM to the actual operation and maintenance of an APM. These contractual aspects primarily involve the contractual procurement options for securing the O&M services. Although it is ultimately the terms and conditions of the O&M contract that specify the performance measures discussed in this report, the purpose of this transitional chapter is not to discuss in detail the particulars of those terms and conditions. Rather, this chapter offers a high-level overview of four different methods for procuring O&M services. These methods are the historic sole-source method of procuring O&M services, the more recent competitive procurement of O&M services, in-sourcing the O&M services to airport staff, and combining a competitive procurement with a sole-source contract for parts and technical support. This chapter compares these four procurement options via three primary measurement factors (cost, risk, and other) and offers a summary of this comparison. Lastly, this chapter summarizes the O&M contract's relationship to performance measurement.

Photo: www.bombardier.com

Maintenance Facility at San Francisco International Airport

3.1 Recent Developments in Procuring Ongoing O&M Services

Since the publication of *ACRP Report 37,* several developments in the O&M procurement area have occurred or are occurring at the time of publication of this guidebook. These include legal precedents, changes to what were formerly typical O&M contract durations, and internal changes within the O&M contract proposer pool (i.e., those companies capable and willing to propose on such contracts).

3.1.1 Legal Precedents

Airport authorities that govern airports of the physical size and operational intensity that necessitate an APM are public entities. Such authorities are usually a city (or county) department, an arm of a city (or county) department, or an independent, quasi-governmental body such as a com-

Photo: www.bombardier.com

Multiple Trains in Maintenance Facility at Hartsfield–Jackson International Airport

mission, board, or council. Regardless of the particulars, each has legally empowered governmental authority and is an entrusted curator of public money. As such, the most common contracting method used by airports is design–bid–build, also known as competitive public low-bid contracting, where the contract award is ultimately based on competing bids with the lowest price constituting the winning bid. This is arguably held as the most effective measure of protecting and ensuring proper and best use of public money and in most cases is legally dictated. Thus, sole-source contracting without good reason and/or justification by a public entity can be construed (either legally, politically, or publicly) as circumventing public bidding laws. The terms and conditions by which a public entity can legally engage in sole-source contracting differ by state. Some state statutes are relatively lenient, with many specific exceptions to public low-bid contracting that will allow sole-source contracting. Such exceptions may involve the high tech nature or availability of the product that is being contracted (such as an APM system). Some states, on the other hand, allow virtually no exceptions to public low-bid contracting.

With regard to O&M contracting specifically, legal precedent has allowed continuing O&M contracts to be sole sourced to the original APM supplier (in all locations where this has been legally allowed). Historically, there were exceptions where the initial supplier had gone out of business, leaving no alternate but put the O&M services out for competition. Circa 2005, from the seed of these few exceptions, some legal departments opined that the very precedent of the few O&M contracts that were successfully put out for competition negated the option of sole sourcing. Within this same time frame, some airport authorities chose to put their continuing O&M contracts out for competition in the interest of seeking cost savings, thus adding to the number of precedents for competitive O&M contracting. Although it cannot yet be confirmed as a future trend, the possibility exists that if legal opinions continue to fall on the side of denying sole-source due to the increasing number of competitively bid O&M services, a time could come where the competitive precedent will be so overwhelming that few legal opinions could justify sole sourcing at all. If this were to occur, it would be a major paradigm shift in APM O&M contracting. Informal discussions with major APM O&M providers reveal that they are aware of this possibility.

3.1.2 O&M Contract Durations

As noted in Chapter 11 of *ACRP Report 37,* historically the typical time period for initial O&M services has been 5 years. Typically, renewals of the contract for continuing O&M services have also been 5 years. Recent contracts for continuing O&M services, either competed or sole sourced, have been longer. Some examples include a base contract of 5 years with option years that can be approved for a total contract duration of up to either 7 or 8 years. Other examples have a base contract of up to 8 years. One example has a base contract of 10 years.

These longer durations ease the administrative burden on airport authorities simply because they need not engage in the contract administration work necessary to extend the O&M services as often. If the services are put out for competition, this contract administration work involved is particularly substantial.

These longer durations also offer the O&M provider a contractual certainty that can allow it to implement capital investments in the APM system that are desired by the owner. One large airport with a large airside APM recently included provisions and funding for midlife improvements to the

Photo: Lea+Elliott, Inc.

Single Train in Maintenance Facility at Detroit Metropolitan Wayne County Airport

APM system that were purposely built into the second generation O&M contract. The terms and conditions of this contractual aspect provided much flexibility in the type of improvements and the schedule for their implementation to ensure that work was done only when needed and as needed. This innovative approach changes the implementation of midlife system improvements to a process instead of an event because typically such work is accomplished in one specific time window under separate contract from the O&M contract. By doing what is needed when it is needed under the ongoing O&M contract, gains in efficiency should be made in terms of dollars, effort, and (lack of) system disruption.

3.1.3 O&M Contract Proposer Pool

The O&M contractor pool, or those companies that are willing and capable of providing APM O&M services, is small and likely to remain small, even with the recent trend of competitive procurement. Chapter 11 of *ACRP Report 37* best explains this by stating that "the APM industry is highly specialized, with each supplier's system being proprietary in nature. Thus, there has historically been no established competitive market for APM O&M services, and the universe of responsible third parties capable of providing such services remains very limited despite the recent solicitations." Even among the initial APM suppliers, some small suppliers are not capable of providing O&M services for larger APM systems due to major technological differences such as cable propulsion versus a self-propelled system or the raw scale differential of the APM system and/or size of the provider company.

Although the provider pool remains small, changes have occurred within the pool subsequent to the publication of *ACRP Report 37.* Examples include one significant third-party O&M provider that has apparently left the market as evidenced by their not bidding on recent O&M competitive solicitations commensurate with their past work. Another example involves a major APM supplier of new systems that has opened several large APMs in the United States over the last several years, but who has yet to venture into proposing on O&M services for other suppliers' systems. However, informal discussions with this supplier indicate that providing O&M services for systems implemented by other suppliers may be in their business plan for the future. Another example involves a major supplier of cable-propelled systems that has apparently left the supplier pool in terms of providing new systems. However, this supplier continues to provide O&M services for their existing systems and in one case competed to provide O&M services for a system by another supplier.

Efforts by an APM O&M provider to protect and maintain its position within the provider pool are understandable because installing an APM system represents a one-time profit, whereas O&M services provide a revenue stream into perpetuity—or for at least as long as the provider can successfully retain the O&M contract. This difference in the revenue streams is universal to all APM suppliers that are also O&M providers. Recently, as competition has become more common, some within the proposer pool have taken specific measures to help secure their positions. One example is taking a corporate stance of not providing technical assistance or proprietary parts directly to a competitor that is providing O&M services for their system. However, such a stance typically does not preclude providing technical assistance or proprietary parts directly to the owner via a separate small, on-call contract. Considering that the owner could then pass the technical assistance or parts to their contracted third-party O&M provider, one might wonder how effective such a corporate stance could be. Apparently, this corporate stance can be somewhat effective because recent industry experience has indicated that although such pass-throughs for proprietary parts do occur, they typically do not occur with the speed of delivery for the parts or reasonableness of cost for the parts compared to situations where the supplier holds the contract directly with the owner.

Photo: Lea+Elliott, Inc.

Two-Car Train in Maintenance Facility at Dallas-Fort Worth International Airport

3.2 Procurement of O&M Services: Contractual Options

Chapter 10 (APM System Procurement) and Chapter 11 (Operations and Maintenance) of *ACRP Report 37* include information about contracting for O&M services. Section 10.2.5 includes a discussion of the design–build–operate–maintain (DBOM) method of APM procurement. The DBOM method, sometimes referred to as "super turnkey," includes an initial period of O&M services as part of the APM system procure-

Photo: Lea+Elliott, Inc.

Elevated Maintenance Facility at George Bush Intercontinental/Houston Airport

ment. The reader is particularly encouraged to read Chapter 11, which includes an overview of different O&M procurement options, including three of the four methods that are discussed in this section. Chapter 11 also addresses the procurement of future O&M periods and offers examples of competing APM O&M services.

There are differences between and similarities in the initial procurement of O&M services at the time of APM system implementation and the future/continuing procurement of O&M services for a seasoned APM system. The focus of this chapter is the procurement of ongoing O&M services. The following four procurement methods are thus presented with the prerequisite assumption that the subject APM system is an existing system with O&M services that have reached a point in their contractual timeline that allows the owner an opportunity to consider different procurement options.

3.2.1 Option 1: Sole-Source Procurement of O&M Services

Procuring ongoing O&M services via a sole-source contract with the original supplier of the APM has historically been the procurement method used most often. One reason for this is that the APM industry is highly specialized, with each supplier's system being proprietary in nature. Thus, there has been no historical development of an O&M contractor pool or those companies capable and willing to provide O&M services for an APM system other than their own. Also, there have been no known problems with the original supplier continuing as the long-term O&M provider. It is reasonable to assume that the development of a long-term familiarity with the APM's operation and maintenance, as well as a long-term proven relationship between the owner and the O&M provider, contributed to the best interests of the owner. It can also be reasonably assumed that these factors contributed to good APM system performance and thus contributed to the best interests of the public.

3.2.2 Option 2: Competitive Procurement of O&M Services

Some recent examples of procuring ongoing O&M services for APM systems have departed from the historic precedent of sole sourcing the services. All of these departures have a common factor that is key to the procurement philosophy, and that common factor is competition. This competition, in turn, helps ensure that the owner realizes the lowest price for the O&M services. In all cases, this quest for low cost appears to be the sole reason for the competitive procurement, and as previously stated, no examples are known where there was a problem with the technical performance of the original O&M provider.

There are many specific contractual approaches that are available to effect a competitive procurement of O&M services. These procurement types differ by what is desired by the owner and/or what is allowed by the specific state statutes where the airport and APM reside. These procurement types are referred to by a variety of colloquial and contractual names such as "best value," "request for competitive sealed proposals," and "competitive two-step," whereby technical qualifications and price are solicited separately. It is not the intent of this report to examine the particulars of these procurement types because the airport's contract administrators and legal staff will already be well versed in the available options if a competitive procurement is desired.

In terms of these competitive procurements being referred to as "recent," it should be considered that the APM industry is more than 40 years old, spanning from the late 1960s to the present. Although the APM industry is young in comparison to other industries such as railroads or even the airline industry, it should also be considered that all competitive procurements within the 40+ year-old APM industry have occurred within the last 6 years.

3.2.3 Option 3: In-Sourcing O&M Services to Airport Staff

Another method to procure ongoing O&M services for an APM system is to in-source the services to airport staff. This could involve the staff of an existing airport department, or if warranted, could involve the creation of a new department with new staff dedicated to the O&M of the APM. Although having in-house staff provide O&M services for a transit system is not rare in urban settings (including some urban APMs), it is fairly uncommon for airport APM systems. The few examples are unique in how they came to be. For example, one large airport with a large APM has a split of O&M services, with in-house staff handling the system's operation while the original APM supplier is under contract to provide the maintenance services. This arrangement was possible because this particular airport already had a ready pool of employees versed in APM O&M functions from a previous-generation APM on the airport. Most of the supplier's employees versed in the O&M of this previous APM had joined the airport's staff via mutually agreeable contractual arrangements among all parties. A more common variation of in-sourcing APM O&M services involves only a partial in-sourcing. In these examples, the higher-level management functions are handled by a relatively few airport staff, with the majority of the physical work being performed by a contracted O&M provider. Another fairly rare variation involves a reversal of this example. In this case, the majority of the physical work is accomplished by in-house staff with the added resource provided by retaining a few on-site staff members of the original APM supplier. This on-site presence of the original supplier may involve only a single staff member.

3.2.4 Option 4: Competitive Procurement with Technical and Parts Support Sole Source Contract

Once the decision has been made by an airport authority to put the ongoing O&M services for their APM out for competition, the outcome cannot be predicted and may result in either the original APM supplier being selected or a third-party O&M provider being selected. There is not yet enough case history to offer odds on which entity is more likely to be successful. However, there is enough case history to suggest that when a third party is selected to provide O&M services, the original APM suppliers have been disinclined to provide technical support and proprietary parts to their competitors. This is an understandable business model when considering the original supplier's desire to retain its position of providing O&M services for its own systems. A contractual means for the owner to deal with this issue of technical support and proprietary parts is to supplement the primary contract with the third-party O&M provider with a smaller, secondary sole-source contract with the original APM supplier exclusively for technical support and proprietary parts. This approach could include a single contract or separate contracts for the technical support and proprietary parts, respectively. Most typically, these supplementary contracts with the original suppliers are set up as time and materials contracts with a not-to-exceed value over the same duration of the primary O&M provider's contract. The supplementary contracts are typically administered as on-call contracts, with the technical services and/or parts being requested and paid for only when needed. Legal precedent in most states is more likely to allow these small on-call contracts to be sole sourced due to their highly proprietary nature as opposed to the primary O&M contract.

3.3 Measurement of O&M Procurement Methodology Criteria

The four O&M procurement options presented in Section 3.2 differ significantly in contractual content as well as their practical application to the daily operation and maintenance of an APM system. Differences in an APM system's size, complexity, and legal and contractual environment, as well as many other factors of the APM system, can have a substantial influence on which of the aforementioned procurement options is most applicable to a particular system. Nevertheless, there are certain criteria that can appropriately be applied to each of the four procurement methods in an effort to quantify and measure the advantages and disadvantages of each. These "measurement factors," as they will be referred to hereafter, are cost, risk, and a collection of other factors. These three major categories of measurement factors can be further subdivided into more specific measurement "sub-factors," as they will be referred to hereafter. All of these factors can be ranked for each of the four O&M procurement methodologies. Although such ranking will obviously be somewhat subjective in nature, actual industry experience with the different methodologies has revealed some consistent and repeatable aspects of each. A large international airport with a large airside APM system recently used the analysis described in this chapter to evaluate, and ultimately

Photo: Lea+Elliott, Inc.

On-Grade Maintenance Facility at Phoenix Sky Harbor International Airport

select, the most appropriate procurement methodology for its next-generation O&M contract. Although the results obtained for that one particular airport cannot be assumed to be universally applicable, there is again industry experience that indicates such results can at least be deemed typical. Thus, an abbreviated version of that approach is presented in this chapter without any specifics applicable to that airport. The intent is to offer a general outline of an analysis that can be usefully adapted and emulated by other airports in their quest to objectively evaluate procurement methodologies for ongoing O&M services.

In this section, each of the three main measurement factors, cost, risk, and other, are defined and discussed along with the sub-factors applicable to each. Ranking of the three measurement factors along with their associated sub-factors is shown in tabular format with a figure dedicated to each of the three main factors. Ranking is defined as "positive," "neutral" or "negative." If ranking does not apply, "N/A" is shown. Lastly, a summary figure is presented and discussed. The particular rankings presented are based on industry experience to date. Specifically, the rankings are an assemblage of the results from the procurement efforts of the large airport previously mentioned as well as the five examples outlined in Chapter 11 of *ACRP Report 37.* The rankings may be considered representative based upon industry experience to date but should not be considered absolute because such experience is limited. When applying the methodology of the case studies to other airport APM systems, the ranking of the measurement factors should be tailored to the legal, contractual, and operational environment of that particular airport APM system.

3.3.1 Measurement Factor: Cost

As previously stated, cost, or more specifically, the quest for the lowest cost, is the apparent primary reason for airport authorities recently departing from the historic contractual model of sole sourcing ongoing O&M services. Thus, in comparing the four contractual procurement options, cost is an important measurement factor. See Figure 2 for rankings for the cost measurement factor.

3.3.1.1 Implementation Cost

The first cost to be incurred by the airport authority is the cost of implementing the new, ongoing O&M contract, which will include the following sub-factors:

In-House Costs (Initial Costs). These costs include the administrative time spent by in-house airport staff in setting up or soliciting the contract. A competitive solicitation includes many unknowns and will likely involve iterative questions and answers with proposers, resulting in addenda. The option involving supplementary contracts for technical support and proprietary parts, by its nature, involves the administration of multiple contracts, which increases the administrative burden.

O & M PROCUREMENT METHODOLOGY CRITERIA

MEASUREMENT FACTOR: COST

O & M PROCUREMENT METHODOLOGY		COST					COMMENTS
		IMPLEMENTATION		BASE PRICE	ESCALATION		
		In-House Costs (initial)	Ongoing Administrative Costs		Labor	Parts, Spares & Consumables	
OPTION I	Sole-Source Procurement of O & M Services	○	○	⊖	⊖	⊖	
OPTION II	Competitive Procurement of O & M Services	●	⊖	○	⊖	●	Negative scores based on industry experience.
OPTION III	In-Sourcing O & M Services to Airport Staff	⊖	⊖	⊖	⊖	●	
OPTION IV	Competitive Procurement with Technical and Parts Support Sole Source Contract	●	⊖	○	⊖	●	Negative scores based on industry experience.

LEGEND: ○ POSITIVE ⊖ NEUTRAL ● NEGATIVE

Figure 2. Rankings for cost measurement factor.

Ongoing Administrative Costs. These costs include the administrative burden incurred over the life of the contract(s) and are not typically as intense as the initial administrative burden incurred when setting up the contract(s). The sole-source option typically has a slight advantage because it is assumed it may more easily be set up with contractual features that ease ongoing administrative burden such as a lump sum schedule of payments, for example.

3.3.1.2 Base Price

This cost refers to the total cost of the O&M services paid out over the life of the contract. Although O&M costs are typically paid monthly and allocated by year within the airport's fiscal year budget, it is typical that the total cost of the contract must be covered by the airport's financial resources at the time of award.

As previously stated, not enough case history exists to predict which provider is most likely to win a competitive procurement. However, it is a widely held contractual axiom that competition is a powerful incentive for all proposers to offer their very best (lowest) price. Thus, it can be reasonably assumed that the contractual options involving competition have an advantage in the measurement factor of base price.

3.3.1.3 Escalation Cost

Following the implementation cost and base cost of the O&M contract, the airport authority must be prepared to cover escalation costs. Often, the multi-year O&M contract is set up with pre-established escalation clauses built into the contract. Such clauses may provide for a reasonable set amount of yearly escalation that may be adjusted if various accepted indices indicate such adjustment is warranted. The airport's contract administrators will have the expertise to set up escalation clauses within the contract that fairly protect the interests of all parties. The following two sub-factors should be considered with regard to escalation.

Labor. Escalation of labor costs is the easier of the two sub-factors to address because numerous published cost indices assist in verifying and/or establishing such costs. Such indices vary from common to specialized. The airport's contract administrator will be familiar with the most appropriate indices to apply.

Parts, Spares, and Consumables. Verifying the actual escalation of the costs for parts, spares, and consumables, particularly if they are proprietary, is difficult because no specific indices exist to gauge or verify such costs. Because cost escalation for these items can be considered to be somewhat built into a sole-source contract, the sole-source procurement option has the advantage with regard to this sub-factor. Because it is understandable and it can be expected that any supplier will strive to keep its actual costs for these items closely held, all other procurement methods have a considerable disadvantage with regard to this sub-factor.

3.3.2 Measurement Factor: Risk

Because airport APM systems are critical to ongoing airport operations (particularly those APM systems of a must-ride nature), and because all involve the health, safety, and welfare of the public, risk is an important measurement factor. See Figure 3 for rankings for the risk measurement factor.

3.3.2.1 Continuity Disruption

Continuity disruption refers to the risk of disruption attributable to the procurement option that manifests itself in disruption to the operations and maintenance of the APM. Examples of such disruption are a drop in system availability or an increase in downtime events. The following two sub-factors can be considered with regard to continuity disruption.

Initial. Initial disruption includes any disruption attributable to the initial hand-off or transitional period between two contracts resulting in different O&M providers. The sole-source procurement option has by far the least risk with regard to this sub-factor because there would be no hand-off or transition.

Ongoing. Ongoing disruption includes any disruption attributable to changes in staff. It is assumed that the procurement options that use the original APM supplier or the airport's in-house staff have a depth of replacement staff that would give them a slight risk advantage with regard to this sub-factor.

3.3.2.2 Technical Expertise

Technical expertise refers not only to the expertise of the on-site O&M staff but also to the corporate expertise and resources (both human and physical) available that can be considered as an available backup to on-site resources. In terms of risk, it is the lack of or the disruption of these resources that is relevant.

Depth and Availability of Experienced Labor Pool. With regard to this sub-factor, the sole-source procurement option resulting in the original supplier providing the labor has an advantage and the least risk. Even if a third-party O&M

O & M PROCUREMENT METHODOLOGY CRITERIA

MEASUREMENT FACTOR: RISK

CONTRACT REPLACEMENT OPTIONS		RISK: CONTINUITY DISRUPTION		RISK: TECHNICAL EXPERTISE			RISK: LEGAL ISSUES		RISK: PROPOSER POOL	RISK: SAFE & SECURE OPERATIONS			COMMENTS
		Initial	Ongoing	Depth & Availability of Experienced Labor Pool	Availability & Speed of Delivery of Parts & Spares	Parts, Hardware & Software Long-Term Sustainability	Initial	Ongoing		Availability (*routine*)	Reliability (*routine*)	Response to "Non-Routine" Circumstances/ Incidents	
OPTION I	Sole-Source Procurement of O & M Services	○	○	○	○	○	⊖	○	N/A	○	○	○	
OPTION II	Competitive Procurement of O & M Services	●	⊖	●	●	⊖	⊖	⊖	●	⊖	⊖	●	
OPTION III	In-Sourcing O & M Services to Airport Staff	⊖	○	○	●	⊖	⊖	⊖	N/A	⊖	⊖	⊖	*Assumes original supplier representative contracted with access to full original supplier resources. Assumes airport hires many original supplier staff.*
OPTION IV	Competitive Procurement with Technical and Parts Support Sole Source Contract	⊖	⊖	⊖	●	⊖	⊖	⊖	●	⊖	⊖	⊖	*Assumes original supplier representative contracted with access to full original supplier resources. Assumes third party hires many original supplier staff.*

LEGEND: ○ POSITIVE ⊖ NEUTRAL ● NEGATIVE

Figure 3. Rankings for risk measurement factor.

provider is a large APM supplier with a large backup labor pool, it is likely not a labor pool versed in the specifics of the APM technology at hand.

Availability and Speed of Delivery of Parts and Spares. This sub-factor, like the previous sub-factor involving the labor pool, incurs the least risk by sole sourcing the original APM supplier. As with the labor pool, even if a third-party O&M provider is a large APM supplier with an excellent system of parts warehousing, tracking, and delivery for their own APM systems, these parts are not the parts needed for the specific APM technology at hand.

Parts, Hardware, and Software Long-Term Sustainability. This sub-factor again favors the procurement option that sole sources the original APM supplier in terms of reducing the risk of losing long-term sustainability of parts, hardware, and software. It could be argued that a third-party O&M provider could, over time, make strides in providing and sustaining the supply of these items. However, the more likely real-world scenario is that the original supplier would continue to evolve, change, and improve upon these items, leaving a third-party O&M provider in an increasingly untenable situation with regard to this risk.

3.3.2.3 Legal Issues

There is little risk of legal issues disrupting the smooth flow of O&M services in any of the procurement options, and in both of the following sub-factors, risk is nearly equal (and neutral) among all options.

Initial. The initial effort and time involving legal inputs and opinions is virtually equal for all procurement options because the primary product of the legal efforts will be the determination of which procurement options are available and what particulars must be incorporated to ensure the legality of the procurement. There is little risk involved in this process.

Ongoing. With regard to ongoing legal issues and risk, it can be assumed that the sole-source procurement methodology resulting in the selection of the original APM supplier has a slight advantage over the other procurement methods. This is based on the assumption that once awarded, this contract would likely incur no further legal issues at all.

3.3.2.4 Proposer Pool

Figure 3 indicates "N/A" for the procurement options involving sole sourcing and in-sourcing the O&M services with regard to the proposer pool. This is because these two options do not involve the proposer pool. The other two procurement options that involve a third-party O&M provider or the small on-call contracts with the original supplier are shown with a negative risk ranking in consideration of the possible contractual complications. For instance, an upstart third-party O&M provider might propose an unrealistically low price due to its lack of understanding of the scope of real-world O&M requirements. The contractual and legal time and effort required to resolve this situation (such as finding the proposer not responsible) could risk complications if it were to happen within a timeframe of imminent expiration of the existing O&M contract.

3.3.2.5 Safe and Secure Operations

All APM systems at airports operate in an environment with unique prerequisite requirements for safe and secure operations that typically go beyond the operational requirements for urban or entertainment venue APM systems, particularly in a post-911 environment. For instance, anti–air-piracy and anti-terror considerations are aspects of an airport APM's operation that are less important (or nonexistent) in non-airport APMs. In addition, because an airport APM's operation is typically tied to the airport's and airlines' operations, a disruption to APM operations risks a severe negative impact to the traveling public. Thus, to reduce risk, an airport APM must operate with very high availability and reliability. The following three sub-factors address this risk with regard to the procurement options.

Availability (Routine). The service availability of an APM system is discussed in depth in subsequent chapters of this report. For the purposes of this transitional chapter, it is sufficient to explain that an APM's availability is not simply the percentage of time it operates versus the time it is out of service. Rather, availability is calculated by various methodologies, and the important point is that an airport APM's availability must consistently be very high on a routine, day-to-day basis. This high availability should be achievable via any of the four procurement methods, although sole sourcing to the original supplier may incur a small advantage due to the previously discussed issues involving technical expertise.

Reliability (Routine). Reliability is not synonymous with availability, although poor reliability could obviously negatively impact an APM's availability percentage. Reliability refers more to the required degree of internal operational and maintenance efforts and how they are effectively applied to the APM system to ensure a reliable system. High reliability should be achievable via any of the four procurement methods, although, again, a slight advantage is assumed for the sole-source method due to the previously discussed issues involving technical expertise.

Response to Non-Routine Circumstances/Incidents. The previous two sub-factors considered aspects of routine, day-to-day APM operations. This sub-factor considers the risk involved with non-routine circumstances or incidents. An example would be the failure of a vehicle's guide wheel that, in turn, damages hundreds of feet of power rail along the guideway—a length far in excess of the length of replacement power rail on hand at the site. In a rare example such as this, the sole-sourced original supplier would have the advantage of its home office and corporate resources being able to rapidly respond and repair the damage in order to resume operations. A third-party O&M provider would not have such resources and the APM would likely sustain a much longer service outage.

3.3.3 Measurement Factor: Other

In addition to cost and risk, the following sub-factors constitute a category of other measurement factors that may be affected by the different procurement methods. See Figure 4 for rankings for the "other" measurement factor.

3.3.3.1 Community Participation

Airports are typically held in esteem by the local communities they serve, and in the case of large international airports, the airport typically serves as a substantial economic engine for its host city and region. Experience has shown that airport authorities typically strive to keep the positive economic effects of the airport localized, and accordingly, strive to procure and award contracts with consideration given to the following two sub-factors.

Opportunities for Minority, Woman, and/or Disadvantaged Business Enterprises. As public entities, airport authorities typically have well-developed programs designed to promote contractual opportunities for local businesses certified as minority, woman, and/or disadvantaged business enterprises (M/W/DBEs). This sub-factor is essentially ranked equally and as neutral among the procurement methods, with the exception that it is not applicable with regard to the in-sourcing method. No major APM O&M providers are known to be M/W/DBE certified, and successfully meeting local M/W/DBE goals has been historically challenging for O&M providers because the specialized nature of the work requires that it be performed by their own forces. Typically, M/W/DBE goals have been met by the O&M provider subcontracting to local certified businesses for temporary and/or administrative office staff, janitorial services, shipping services, office supplies, and any other such services that are applicable.

Local Participation. In addition to promoting M/W/DBE participation, and for basically the same reasons, airport authorities typically strive to promote local participation in the contracts they award. This sub-factor has also been ranked equally and as neutral among the procurement methods, again with the exception that it is not applicable with regard to the in-sourcing method. Because of the small size of the O&M provider pool, it is extremely unlikely that

O & M PROCUREMENT METHODOLOGY CRITERIA

MEASUREMENT FACTOR: OTHER

CONTRACT REPLACEMENT OPTIONS		OTHER: COMMUNITY ACCEPTANCE/ PARTICIPATION		OTHER: FUTURE SYSTEM EXPANSION		COMMENTS
		M/W/DBE Opportunities	Local Participation	Modifications, Upgrades/ Enhancements to Existing System	Extension/ Expansion of Existing System	
OPTION I	Sole-Source Procurement of O & M Services	⊖	⊖	○	○	
OPTION II	Competitive Procurement of O & M Services	⊖	⊖	●	●	
OPTION III	In-Sourcing O & M Services to Airport Staff	N/A	N/A	⊖	⊖	*N/As assume inconsequential percentage of work.*
OPTION IV	Competitive Procurement with Technical and Parts Support Sole Source Contract	⊖	⊖	●	●	

LEGEND: ○ POSITIVE ⊖ NEUTRAL ● NEGATIVE

Figure 4. Rankings for "other" measurement factor.

a prospective O&M provider will reside in the host city and be considered a local company. Thus, the goal of enhancing local contractual participation has been historically challenging and is usually met in the same way M/W/BE goals have been met. Assuming the M/W/DBE participants are local businesses, both of these sub-factors could be satisfied with the same companies subcontracted by a prospective O&M provider.

3.3.3.2 Future System Expansion

For purposes of this discussion, "expansion" is broadly defined as a change to the existing APM system, including an extension to or expansion of the existing APM system. The possibility exists that such expansion work could occur during the term of a particular O&M contract, either by unforeseen necessity or by planned design. It is possible that various types of expansion work could be accomplished by separate contract, could possibly be added by change order to the ongoing O&M contract, or may have been already included in the O&M contract award as in the example discussed in Section 3.1.2. In any case, a procurement methodology that ensures selection of the original APM supplier would have the greatest advantage, while a procurement methodology that results in a third-party O&M provider would have the greatest disadvantage. This is again due mostly to the corporate resources of the original supplier. The following two sub-factors amplify this point.

Modification, Upgrades/Enhancements to Existing System. The possibility of modifications and/or upgrades to the existing system could take many forms and could involve any number of the subsystems of the APM. These include the automatic train control system (ATC), vehicles, communications, graphics, the central control facility, and a virtually endless assortment of other possibilities. However, all of the possibilities have commonality in that the original supplier would have a substantial advantage in performing modifications and/or upgrades and in many instances would be the sole entity with the ability to do so. It is appropriate, and not unlikely, that this type of modification or upgrade/enhancement work could be performed under an O&M contract.

Extension/Expansion of Existing System. An extension of the existing APM system could involve a physical extension of the guideway in order to serve additional facilities. An expansion of the existing APM system could also involve a physical extension or could expand the APM system's capacity by increasing train length or adding operating trains to the fleet. As with the previous sub-factor, extending and/or expanding the APM system could involve a plethora of possibilities, and again, the original supplier would have a substantial advantage. Although it is possible that some of this type of work could be performed under an O&M contract, it is far more likely that such major work would be performed under a separate contract. This highlights a possible scenario where a physical expansion or extension to an existing APM system is performed by the original APM supplier while the existing system is being operated and maintained by a third party. This scenario actually occurred at a major international airport and required careful coordination between the two entities. A disadvantage from the owner's perspective was that the owner did not have a single point of responsibility for the expansion work, which would not have been the case if the original supplier had held the O&M contract.

3.3.4 Summary

The summary in Figure 5 indicates that in terms of the measurement factors, the sole-source procurement option has the most positive score, while the procurement options allowing a third-party O&M provider have the lowest score. While not intending to diminish the impact of the other measurement factors, these results indicate that an airport authority's preference in choosing an ongoing O&M procurement option can be primarily distilled to an issue of cost versus risk—specifically, the possibility of cost savings versus the possibility of increased risk. Possible cost savings are a worthy goal for any public entity and, if realized, are a tangible and measurable advantage. On the other hand, the possibility of various kinds of increased risk is a subjective and elusive factor—at least until something negative actually occurs as a result of the increased risk. Real-world experience is currently not substantial enough and does not contain enough specific examples to predict the outcome of the cost-versus-risk aspect for the procurement types that allow a third-party O&M provider. There are positive real-world examples of a third-party O&M provider providing the owner with increased availability percentages for APM systems. There are also negative real-world examples of accidents involving APM systems, sometimes with personal injury to passengers, while the system was under contract to a third-party O&M provider. The real-world experience of original suppliers providing ongoing O&M services has a much longer history, and despite this much longer time frame for the possibility of negative incidents, it is comparatively devoid of accidents and personal injury to passengers.

Despite the sole-source procurement option having the highest score, the purpose of this summary is not to make a definitive recommendation, particularly in light of the fact that some owners will not have the legal flexibility to even consider all of the procurement options. Rather, as previously stated at the beginning of this section, the intent is

O & M PROCUREMENT METHODOLOGY CRITERIA
SUMMARY

CONTRACT REPLACEMENT OPTIONS		SUMMARY			COMMENTS
		RISK	COST CONTAINMENT	OTHER	
OPTION I	Sole-Source Procurement of O & M Services	○	⊖	⊖	
OPTION II	Competitive Procurement of O & M Services	●	⊖	●	*Lower base price partially countered by other cost factors. Parts issues assumed to offset lower 3rd party cost.*
OPTION III	In-Sourcing O & M Services to Airport Staff	⊖	⊖	⊖	
OPTION IV	Competitive Procurement with Technical and Parts Support Sole Source Contract	●	⊖	●	*Lower base price partially countered by other cost factors. Parts issues assumed to offset lower 3rd party cost.*

LEGEND: ○ POSITIVE ⊖ NEUTRAL ● NEGATIVE

Figure 5. Measurement factor summary.

to offer a general outline of an analysis that can be usefully adapted and emulated by airports in their quest to objectively evaluate procurement methodologies for ongoing O&M services. For example, if such an evaluation indicates that the increased possibility of specific risks at a specific airport is not great, the ranking of the risk measurement factors can be adjusted accordingly. If such an evaluation does not involve the possibility of system expansion, then the measurement factors involving expansion can be considered superfluous. Or, if such an evaluation commences with a prevailing goal of cost savings, the ranking of the cost measurement factors can be adjusted accordingly. By making such adjustments within the framework of the analysis used, results should be accurate to the degree of aiding and adding credibility to the decision-making process for choosing the most appropriate O&M procurement option.

3.4 O&M Contract's Relationship to Performance Measurement

Chapter 3 has presented different procurement options for securing ongoing O&M services and has offered a model analysis for comparing the procurement options with various measurement factors. Some of the performance measurement factors show that the type of procurement process and how it is administered can have an effect on the APM system's performance. However, it is ultimately the actual O&M contract and its specific terms and conditions that establish the performance benchmarks for the APM. The actual O&M contract also establishes precisely how that performance is measured. The following chapters elaborate on performance measurements for APM systems at airports and offer specific contractual approaches for such measurement.

CHAPTER 4

Performance Measurement of APM Systems at Airports: The Current Situation

Research of several industry documents shows that current performance measurement of both airport and non-airport APMs is primarily focused on traditional measures of operating system performance (i.e., reliability, maintainability, and availability). Other APM performance measures related to economic efficiency, comfort, and convenience, among others, have received significantly less attention in the literature, if any at all. Some of these measures are applied in other industries, however, and have been considered in the development of the performance measures set forth in this guidebook.

4.1 Historical Performance Measurement of APM Systems at Airports

The documented methods of system performance measurement for airport APMs can be broadly divided into two classes: applied methods and theoretical methods. These classifications are described in the following subsections.

4.1.1 Applied Methods

In general, there are four applied methods used in airport APM performance measurement: the System Dependability Method, the Contract Service Dependability Method, the System Service Availability Method, and the Paris Airport Authority Method. These methods are primarily distinguished from one another by the number of factors measured, grace period durations, whether credit is allowed for partial service operations during failures, and whether capacity is a consideration in any of the measures. The methods and characteristics of each are summarized in Table 1.

Each of the applied methods is described in detail in the following.

4.1.1.1 System Dependability Method

The classical measurement of performance for systems in general, as well as in the APM industry, is the System Dependability Method, as presented in ASCE 21-05, American Society of Civil Engineers, Automated People Mover Standards—Part 1, Chapter 4. This method incorporates three measures of overall system performance: reliability, or mean time between failure (MTBF); maintainability, or mean time to restore (MTTR); and availability (the ratio of MTBF to the sum of MTBF and MTTR). This method allows for the consideration of grace periods for downtime incurred as a result of an incident or failure, and it also allows for downtime credit during partial service operations. Capacity is not considered as part of this method.

4.1.1.2 Contract Service Dependability Method

The Contract Service Dependability Method was developed by U.S. consulting firm JKH Mobility and has been implemented at some APM systems. The method is very similar to the System Dependability Method in that it incorporates the same three performance measures: reliability, maintainability, and availability (RAM). While the older literature revealed that this method previously relied on three sets of the RAM measures (one set called "absolute" RAM, one called "design/operational" RAM, and another called "contract service" RAM), it has today generally evolved into two measure sets—one RAM set where all failures are taken into account and where failures that are considered exceptions are not taken into account. This method generally allows for a grace period of 3 min or less for downtime resulting from incidents/failures.

Concerning the method's treatment of partial service credit and capacity considerations, most of the examples of this method revealed that these are not incorporated as part of the method. There were two exceptions, however. The first

Table 1. APM performance measurement, applied methods.

Method/Measures	No. of Measures	Grace Period	Partial Service Credit	Capacity Considered
System Dependability Method				
Reliability Maintainability Availability	3	yes	optional	no
Contract Service Dependability Method				
Contract service reliability Contract service maintainability Contract service availability	3	3 min	no*	no*
System Service Availability Method				
Service mode reliability Service mode maintainability Service mode availability Fleet availability Station platform door availability System service availability	6	1 head-way	yes	yes
Paris Airport Authority Method				
Contract service availability	1	no	yes	yes**

*In most cases of the literature reviewed.
**During degraded mode operations.

is the method as applied to the pinched-loop APM system at Chicago's O'Hare International Airport. There, the system has the capability to operate around many types of failures because its numerous switches and routing combinations, as well as its bidirectional capability, provide a high degree of flexibility in maintaining service during failures. As such, partial service credit is allowed, and system capacity is considered only so far as to make the calculation of the credit. The formula is complicated by the fact that various train lengths may be operating at the same time, which forces the consideration of both transportation capacity and headway as well as a corresponding set of specific rules. This is not so in the case of the Paris Airport Authority Method that will be discussed later.

The second exception is the method as applied to the dual-lane shuttle APM at Orlando International Airport. Although capacity is normally not considered in this exception at all, a type of partial service credit is allowed in one specific case—during a failure of the scheduled single train/lane operation when the standby train/lane is undergoing maintenance and is unavailable.

4.1.1.3 System Service Availability Method

The System Service Availability Method has been advocated and used by U.S. consulting firm Lea+Elliott since 1994. As a result, it is in wide usage at airport APMs worldwide. The method is distinguished from the other methods by measures that record the performance of subsystems that are most likely to affect passengers. Because the other methods concentrate only on performance as affected by interruptions to system service (i.e., train stoppages), other failures that affect passenger service without interrupting system service are not captured. For example, station platform door failures that deny passengers access to the vehicles affect passenger service and may not be reflected in the measures of the other methods. This method incorporates measures of service mode availability, fleet availability, station platform door availability, and system service availability. The additional availability measures related to fleet and station platform doors ensure that all failures affecting passengers (not just those that interrupt service) are reflected in the overall service availability measure.

The System Service Availability Method also tracks the number of service mode failures, or downtime events, which allows measures of service mode reliability and maintainability to be easily made. These two measures, along with the four availability measures described previously, make up the six measures unique to this method.

This method allows an equivalent of one headway duration or less for a grace period for both incidents/failures and schedule transitions. It also allows for the consideration of downtime credit for partial service operations provided during failures, and it considers capacity as part of its normal measure set rather than during partial service credit only.

4.1.1.4 Paris Airport Authority Method

The Paris Airport Authority (Aeroports de Paris) Method is a variation on the System Dependability Method discussed previously. It was introduced by Aeroports de Paris and ALONEX for Line 1 of the APM system at Roissy Charles-de-Gaulle (CDG) Airport. Unlike the other methods, it calculates contracted service availability on the basis of service unavailability, and in so doing, eliminates from the calculation any need to consider grace periods or the downtime exclusions common to the other methods. (The other methods are similar in that they exclude the consideration of downtime caused by external sources, such as passenger-induced delays, interruptions caused by intrusions of unauthorized persons or objects, and other external sources beyond the control of the system or operating entity.)

Working from the perspective of service unavailability, the goal of this method is to take into account the transportation capacity of the system during periods of degraded mode operations. Providing the ability to earn this partial service credit, and tying the contracted service availability to payment, is an incentive to the operator to provide the best possible transportation capacity during failures. Although the path to calculating the contracted service availability number is different, the partial service credit incentive concept is very similar to the approach used for the Chicago O'Hare APM discussed previously. One significant difference is that whereas the Chicago APM must deal with a specific approach due to its variable-length trains, the CDG APM system does not (it has fixed-length trains). Both of these APM systems, Roissy Charles-de-Gaulle and Chicago O'Hare, are supplied by the same APM system supplier, which may explain some of the similarities in the methods.

4.1.2 Theoretical Methods

The literature review and analysis have also revealed that APM performance measurement has been studied and reported on theoretically. Three papers in particular have been presented in this area.

4.1.2.1 Airport APM Performance Measurement: Network Configuration and Service Availability

The first paper, "Airport APM Performance Measurement: Network Configuration and Service Availability," was presented in 2007 at the 11th International ASCE APM Conference in Vienna. It was written by Wayne D. Cottrell, Associate Professor at California State Polytechnic University, and Yuko J. Nakanishi, President of Nakanishi Research and Consulting, LLC.

This paper examines service availability and reliability and how they are affected by airport automated people mover (AAPM) network configurations and other system parameters. The paper affirms the importance of availability and reliability measurements in the APM industry.

The paper suggests that detailed measures of headway regularity would be useful in an empirical study of AAPM reliability performance. Measures that are set forth include headway adherence, service regularity, headway ratio, headway regularity index, and headway deviation.

The ultimate conclusion is that network configuration affects the reliability and availability of airport APMs, albeit in a limited way due to the limited variety of airport APM networks. Other system parameters such as consist size and the number of in-service trains also affect reliability and availability.

4.1.2.2 Defining and Measuring Service Availability for Complex Transportation Networks

The second paper, "Defining and Measuring Service Availability for Complex Transportation Networks," was presented in 1996 at the International Conference on Personal Rapid Transit (PRT) and Other Emerging Transportation Systems in Minneapolis. It was written by Charles P. Elms, now retired from Lea+Elliott.

The paper first defines measures of service availability in current use and analyzes exact and approximation methods for data collection and computation. It then postulates and explores classical and new definitions of service availability applicable for complex networks such as PRT. Insight is provided for choosing a suitable definition based on the type of transportation network.

The methodology in the paper is based on the classical approach of service mode availability [MTBF/(MTBF + MTTR)], and adjusts for fleet availability and station platform door availability. Ultimately, the methodology outlined in the paper aligns with the System Service Availability Method discussed previously.

4.1.2.3 RAM: Reliability, Availability and Maintainability of APM Systems

The third paper, "RAM: Reliability, Availability and Maintainability of Automated People Movers," was presented in 1989 by John K. Howell at the Second International Conference on APMs in Miami.

This paper discusses in detail reliability theory in particular, as well as the factors that influence reliability (MTBF), maintainability (MTTR), and availability in an APM system. It also describes approaches to specifying contract service requirements based on classical definitions of MTBF, MTTR, and availability. The paper ends with a discussion of RAM monitoring and accountability.

The methodology in the paper is generally based on the classical approach of availability [MTBF/(MTBF + MTTR)] and aligns with the Contract Service Availability Method discussed previously.

4.2 Characteristics of Effective Performance Measurement Systems for APM Systems at Airports

Performance measurement is a type of assessment. It is the ongoing monitoring and reporting of system or program accomplishments, particularly of progress toward pre-established goals.

A key aspect of a successful performance measurement system is that it is composed of a balanced set of a few vital measures. For example, performance measurement of airport APM systems has historically focused on a system availability measurement, often including reliability and maintainability. This is no surprise because these are also the core measures for many other engineered systems composed of numerous, technically complex subsystems designed to work together seamlessly and efficiently as a whole. APM suppliers use these measures in their system designs, and owners use the measures to verify that the technology in which they have invested heavily is performing satisfactorily. It is a natural progression, then, that these same measures be used during the ongoing operation and maintenance of the system after its construction and as the basis for payment to companies contracted to provide operations and/or maintenance services of these systems. While the limited number of these core measures satisfies the "few vital measures" aspect of a successful performance measurement system, they may not be well balanced in the absence of measures that look at the performance of other vital areas of an airport APM system (such as safety), the economic efficiency of the system or O&M service provider, or the quality of service perceived by airport APM passengers, for example.

Besides making up a balanced set of a few vital measures, other aspects of effective performance measurement systems for airport APM systems include that:

- The measurement system be cost effective to implement and sustain,
- The system be reviewed on a semi-regular basis to ensure that the measures are still appropriate,
- Reporting or posting of the measures avoids oversaturation in order to maintain relevance and minimize the desensitizing effect over the long term, and
- The system contain measures that:
  - Are meaningful;
  - Describe how well the goals and objectives are being met;
  - Are simple, understandable, logical, and repeatable;
  - Show a trend;
  - Are unambiguously defined;
  - Allow for economical data collection; and
  - Are timely and sensitive.

Historically, airport APM performance measurement has been meaningful to owners, APM system suppliers, and O&M service providers, but not always reflective or meaningful from the passengers' perspective. As such, "meaningful" is further clarified to mean "meaningful, but representative from all views."

Similarly, the core availability, reliability, and maintainability measures discussed previously have sometimes not been simple since there can be onerous rules, problems collecting data, or interpretational issues. Therefore, this guidebook strives to improve airport APM performance measures in this area to make them more simplistic and straightforward, where possible.

In short, performance measurement focuses on whether a system or program has achieved its objectives, expressed as measurable performance standards. Because of its ongoing nature, it can serve as an early warning system to management, as a vehicle for improving accountability to the public, as a method to document accomplishments, and as a way to compare similar programs and systems, such as other airport APM systems.

CHAPTER 5

Performance Measures for APM Systems at Airports: Recommended Approach

Performance measures for APM systems at airports are organized into a set of seven metrics (shown in Table 2) and are reported along with system and service descriptive characteristics (shown in Table 3) at monthly intervals on Form A and Form B, which are provided in Exhibit A. The measures are developed from the passengers' perspective and therefore generally do not exclude events typically excused (1) under force majeure contract clauses or (2) when outside the control of the system operator.

This section provides the definition, data requirements, data sources, and data collection techniques for the airport APM performance measures, and begins with the definition of the system and service descriptive characteristics that are critical to providing context to the performance measures when the measures are used for comparison purposes among reporting airport APM systems.

5.1 System Descriptive Characteristics

System descriptive characteristics of airport APM systems are descriptors that provide a general understanding of airport APM system size and help put into perspective the performance measures of such systems when they are used to compare performance among other airport APM systems. System descriptive characteristics are likely to remain the same from one reporting period to the next unless a system expansion or reduction has taken place since the last reporting period. The following system descriptive characteristics, to be reported on Form A, are defined in this section:

- Single Lane Feet of Guideway, Mainline
- Single Lane Feet of Guideway, Other
- Routes Operated in Maximum Service
- Trip Time in Maximum Service
- Stations
- Vehicles in Total Fleet

5.1.1 Single Lane Feet of Guideway, Mainline

Single Lane Feet of Guideway, Mainline is defined as the total length of track in the passenger-carrying portion of the system, regardless of direction, and is expressed in single lane (track) feet. For example, if a system contains one mile of dual-lane mainline guideway, this would be expressed as 10,560 single-lane feet (slf) of mainline guideway (5,280 ft/mile × 2 lanes).

This system characteristic does not include guideway in the non-passenger-carrying portion of the system, such as mainline pocket tracks, storage tracks beyond terminals, turnback/switchback tracks, and yard tracks.

Single Lane Feet of Guideway, Mainline plus Single Lane Feet of Guideway, Other is the quantification of all track in the system.

5.1.2 Single Lane Feet of Guideway, Other

Single Lane Feet of Guideway, Other is defined as the total length of track in the non-passenger-carrying portion of the system, regardless of direction, and is expressed in single lane (track) feet.

This system characteristic includes all guideway used in the non-passenger-carrying portion of the system, such as mainline pocket tracks, storage tracks beyond terminal stations, turnback/switchback tracks, yard maintenance and storage tracks, and related shop approach tracks. Single Lane Feet of Guideway, Other also includes track lengths located indoors in the non-passenger-carrying portion of the system, such as vehicle storage and/or maintenance shop tracks.

Single Lane Feet of Guideway, Other plus Single Lane Feet of Guideway, Mainline is the quantification of all track in the system.

5.1.3 Routes Operated in Maximum Service

Routes Operated in Maximum Service is defined as the number of routes operated in the system during the peak

Table 2. Airport APM performance measures.

AIRPORT APM PERFORMANCE MEASURES
Service Availability (one of three approaches to be selected)
Safety Incidents per 1,000 Vehicle Service Miles
O&M Expense per Vehicle Service Mile
Actual and Scheduled Capacity (Peak Versus All Other)
Passenger Satisfaction
Missed Stations per 1,000 Station Stops
Unintended Stops per 1,000 Interstations

period of the day that maximum service is provided during the reporting period, with a route being the unique path a train follows and station stops a train makes from its terminal of departure to its terminal of arrival before changing directions (or in the case of single- or dual-lane loop systems, before beginning the same route again). For example, the Routes Operated in Maximum Service for a dual-lane pinched-loop system would typically be two; for a dual-lane shuttle system, four; for a dual-lane loop system, two; and so on.

Routes Operated in Maximum Service excludes routes implemented to address atypical, failure, or special-event service during the reporting period.

5.1.4 Trip Time in Maximum Service

Trip Time in Maximum Service is defined as the trip time in the system, by route, during the peak period of the day that maximum service is provided during the reporting period, beginning upon the start of the door closing sequence at the originating terminal and ending once all doors are open at the destination terminal (or in the case of single- or dual-lane loop systems, ending once all doors are open at the originating terminal).

This system characteristic includes interstation travel times and dwell times at intermediate stations and excludes dwell times at the origin and destination terminals as well as atypical and failure-related events and operations, such as wayside speed restrictions and onboard vehicle speed limitations.

5.1.5 Stations

The Stations system characteristic is defined as the number of stations in the APM system at which APM trains stop and dwell to carry out the passenger exchange, with a station being the general locale at which passengers can board and alight APM trains, regardless of the configuration or number of platforms at the station. For example, a station with two side platforms separated by a dual-lane guideway is counted as one station.

5.1.6 Vehicles in Total Fleet

Vehicles in Total Fleet is defined as the number of vehicles in the system that are either currently operable or capable of being operable once the appropriate maintenance, cleaning, or other action has been undertaken. For the purpose of this system characteristic, "vehicle" is defined and distinguished as follows:

Car. An individual passenger-carrying unit that cannot operate individually but must be connected and share equipment with other cars to form a vehicle. A car is not a vehicle.

Vehicle. The smallest passenger carrying unit that can operate individually. This may be a single unit or a permanently coupled set of dependent cars. A vehicle can also be coupled with one or more other vehicles to form a train.

Train. A set of one or more system vehicles coupled together and operated as a single unit.

Vehicles in Total Fleet does not include heavily damaged vehicles in need of extensive repair, decommissioned vehicles awaiting disposal, and other similar permanently blocked-up vehicles that would require major repair or refurbishment efforts.

5.2 Service Descriptive Characteristics

Service descriptive characteristics of airport APM systems are descriptors that provide a general understanding of the service and operational aspects of airport APM systems and help put into perspective the performance measures of such systems when they are used to compare performance among other airport APM systems. Service descriptive characteristics are likely to change from one reporting period to the

Table 3. Airport APM system and service descriptive characteristics.

SYSTEM DESCRIPTIVE CHARACTERISTICS	SERVICE DESCRIPTIVE CHARACTERISTICS
Single Lane Feet of Guideway, Mainline Single Lane Feet of Guideway, Other Routes Operated in Maximum Service Trip Time in Maximum Service Stations Vehicles in Total Fleet	Passenger Trips Vehicle Service Miles Vehicles Operated in Maximum Service Vehicles Available for Maximum Service Headway in Maximum Service

next. The following system descriptive characteristics, to be reported on Form A, are defined in this section:

- Passenger Trips
- Vehicle Service Miles
- Vehicles Operated in Maximum Service
- Vehicles Available for Maximum Service
- Headway in Maximum Service

5.2.1 Passenger Trips

Passenger Trips is defined as the number of passenger trips taken on the system during the reporting period, with a passenger trip being made by any individual that uses the APM system to get from one station to another in the system.

It is recognized that there is variability in how, and even if, passenger trips are quantified in airport APM systems. Some systems use automatic passenger counting systems, either installed above train or platform doors or at a common location where passengers enter and exit stations. Because of the open nature of airport APM systems, these automatic counting technologies count global ins and outs and do not track individual passenger movements like fare collection systems in closed transit systems that use turnstiles and tickets. This makes these automatic counting technologies, although convenient, generally less precise than those in closed transit systems.

Other airport APM systems may not use automatic passenger counting systems, but instead estimate APM passenger trips based on actual or forecast parking or airline passenger data.

Still other airport APM systems may quantify APM passenger trips by physically counting passengers on a semi-regular basis using employees or consultants posted on APM station platforms.

It is recognized that airport APM systems may not be able to report the Passenger Trips service descriptive characteristic or may not be able to report it accurately. For these systems, they are encouraged to report at least order-of-magnitude Passenger Trips where possible.

5.2.2 Vehicle Service Miles

Vehicle Service Miles is defined as the total miles traveled by all in-service vehicles in the system during the reporting period, with a vehicle being in service when located in the passenger-carrying portion of the system and when passengers are able to use it for transport.

For example, if an in-service train is composed of three vehicles and the distance the train travels is 4 miles, then the number of Vehicle Service Miles is 12.

Vehicle Service Miles performed during the reporting period can be obtained directly from vehicle hub-o-meter or odometer readings or possibly from the automatic train supervision (ATS) system (control center computer system). Caution needs to be exercised so that miles performed in the non-passenger-carrying portions of the system or while a vehicle is out of service are subtracted from totals that include such mileage.

5.2.3 Vehicles Operated in Maximum Service

Vehicles Operated in Maximum Service is defined as the number of in-service vehicles operated at once in the system during the peak period of the day that maximum service is provided during the reporting period, with a vehicle being in service when located in the passenger-carrying portion of the system and when passengers are able to use it for transport. Vehicles staged as hot-standby or operational spares, regardless of location, are not included.

For example, if during maximum service an airport APM system uses five in-service trains composed of three vehicles each and one train composed of two vehicles in standby at a terminal station, the number of Vehicles Operated in Maximum Service is 15.

Vehicles Operated in Maximum Service excludes vehicles used to address atypical, failure, or special-event service during the reporting period.

5.2.4 Vehicles Available for Maximum Service

Vehicles Available for Maximum Service is defined as the number of vehicles available to be in service at once in the system during the peak period of the day that maximum service is provided during the reporting period, with a vehicle being available when it can be placed in service after no more than a departure test, for example, and without first requiring any maintenance, cleaning, or other similar action. A vehicle is in service when located in the passenger-carrying portion of the system and when passengers are able to use it for transport.

For example, if during maximum service an airport APM system has 29 vehicles in its total fleet, and:

- 20 are in service;
- One is in the maintenance shop but capable of being in service;
- One is in the maintenance shop and being repaired due to failure;
- Three are coupled together on the vehicle storage tracks at the maintenance and storage facility (M&SF), with one of those three in failure; and
- Four are coupled together on the vehicle storage tracks at the M&SF, with none of the four in failure; then the number of Vehicles Available for Maximum Service is 24. Vehicles located in the maintenance shop, regardless of their status, as well as operable vehicles coupled to failed vehicles at the M&SF, are not considered available.

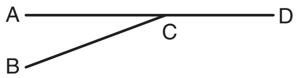


Figure 6. Example route structure on an airport APM system.

5.2.5 Headway in Maximum Service

Headway in Maximum Service is defined as the most frequent headway operated in the system during the peak period of the day that maximum service is provided during the reporting period, with headway being the elapsed time between the same part of consecutive, in-service trains operating in the same direction on the same guideway.

For example, as described in Figure 6, if during maximum service trains operate on separate routes between terminals A and D, between terminals B and D, and between terminals C and D, the Headway in Maximum Service would occur on the guideway with the most frequent headway, or between terminals C and D.

Headway in Maximum Service excludes headways that involve in-service vehicles used to address atypical, failure, or special-event service during the reporting period.

5.3 Airport APM Performance Measures

Airport APM performance measures are the metrics used to track and compare the performance of airport APM systems as seen from the passengers' perspective. There are seven recommended measures, described by title in Table 4, that are to be reported on Form B, which is provided in Exhibit A.

For each measure in this section, the following is provided:

- A definition,
- Data requirements and sources for the measure, and
- Data collection techniques and the calculating and recording of the measure.

Table 4. Airport APM performance measures.

No.	Title
1	Service Availability (choose one of the three approaches below)
	A Tier A Approach
	B Tier B Approach
	C Tier C Approach
2	Safety Incidents per 1,000 Vehicle Service Miles
3	O&M Expense per Vehicle Service Mile
4	Passenger Satisfaction
5	Actual and Scheduled Capacity (Peak Versus All Other)
6	Missed Stations per 1,000 Station Stops
7	Unintended Braking Applications per 1,000 Interstations

To aid with the tracking and calculation of the measures, a Microsoft Excel workbook file containing several spreadsheets (one for each measure) has been provided and made available for download at the summary page for *ACRP Report 37A*, which can be found at http://www.trb.org/Main/Blurbs/166387.aspx. The file allows the user to simply input daily data, and the measures are automatically calculated for the day, month-to-date, and year-to-date.

The forms provided in Exhibit A, which are to be used in reporting the measures and descriptive characteristics discussed in Sections 5.1 and 5.2, have also been made available for download from the *ACRP Report 37A* summary page, and can be completed electronically for easier distribution and tracking.

All of the measures described in Table 4 should be implemented. The airport APM performance measures are defined in detail in the following sections, beginning with Airport APM Performance Measure #1, which includes three approaches for determining Service Availability. The Tier A approach is the least complex and least comprehensive of the three approaches, whereas the Tier C approach is the most complex and most comprehensive of the approaches.

For Airport APM Performance Measure #1: Service Availability, choose only one of the three approaches described in Sections 5.3.1, 5.3.2, and 5.3.3.

5.3.1 Airport APM Performance Measure #1: Service Availability (Tier A Approach)

5.3.1.1 Definition

Service Availability (Tier A Approach) is the percentage of time service has been available on the airport APM system, as defined herein. Recognizing that headway regularity is of significant importance to airport APM users, Service Availability (Tier A Approach) is based largely on headway performance. In an effort to maintain the simplicity and usability of the measure, it deliberately does not attempt to capture all system events that an airport APM user could perceive as a loss of availability. Service availability approaches in subsequent sections become more comprehensive in nature by capturing a greater share of those events, and carry with them a greater level of sophistication as well.

Service Availability (Tier A Approach) is defined as:

$$\text{Daily SA}_A = \left(\frac{\text{AOT}}{\text{SOT}}\right) \times 100$$

$$\text{Monthly SA}_A = \left(\frac{\sum_{d=1}^{m} \text{AOT}}{\sum_{d=1}^{m} \text{SOT}}\right) \times 100$$

$$\text{Yearly } SA_A = \left(\frac{\sum_{d=1}^{y} AOT}{\sum_{d=1}^{y} SOT} \right) \times 100$$

Where:

- SA_A = Service Availability (Tier A Approach).
- AOT = Actual operating time. The total time, in seconds, that the system was operating, calculated by subtracting downtime from scheduled operating time (SOT – D).
- SOT = Scheduled operating time. The total time, in seconds, that the system was scheduled to provide service.
- D = Downtime. The total time, in seconds, of all downtime events.
- *A downtime event* is any of the following:
  - When the actual headway of in-service trains exceeds the scheduled headway by more than 20 sec during the time when the system is scheduled to provide service. This downtime event begins at the departure time of the in-service train that produced the last on-time headway on the scheduled route before the event; it ends at the departure time of the in-service train that produces the first on-time headway on the scheduled route after the event.
  - When any in-service train has an incomplete trip on a scheduled route during the time when the system is scheduled to provide service. This downtime event begins at the departure time of the in-service train that produced the last on-time headway on the scheduled route before the departure time of the train having the incomplete trip; it ends at the departure time of the in-service train that produces the first on-time headway on the scheduled route after the departure time of the train having the incomplete trip.
  - When the first daily departure of an in-service train from the terminal on each scheduled route fails to occur within the time of one scheduled headway during the time when the system is scheduled to provide service. This downtime event begins at the scheduled opening time and ends at the time of the first departure of an in-service train from the terminal on the scheduled route.

  If any of these downtime events occur at the same time or overlap one another, the earliest start time and the latest end time of the events, as defined by the rules herein, are to be used in determining downtime.
- *Headway* is the elapsed time between the same part of consecutive, in-service trains operating in the same direction on the same guideway.
- *In-service train* is a train located in the passenger-carrying portion of the system that passengers are able to use for transport.
- *Incomplete trip* is the trip of an in-service train that fails to make a station stop on the scheduled route or that fails to finish the trip on the scheduled route.
- *On-time headway* is a headway that does not exceed the scheduled headway by more than 20 sec.
- d = Day of the month or year, as applicable.
- m = Days in the month.
- y = Days in the year.

Deliberately employing operating strategies to eliminate or stop the accumulation of downtime by exploiting the intent of the rules herein, especially when those strategies do not benefit the APM user, is not permitted in the context of this system of evaluation (e.g., using a schedule that provides for less frequent scheduled headways than the actual service headways). Inserting additional trains to recover from a downtime event is permitted, but operating additional trains as a routine course over and above what the schedule requires is not. In such a case, the schedule should be modified to reflect the actual operation.

All downtime is to be quantified and assigned to one of the following predefined causal categories:

- Weather-induced. Downtime caused by the weather, such as lightning striking the guideway, or a snow or ice storm.
- Passenger-induced. Downtime caused by a passenger, such as a passenger holding the vehicle doors open or a passenger pulling an emergency evacuation handle on an in-service train.
- System equipment-induced. Downtime caused by system equipment, such as a broken axle on an in-service train, or train control system equipment that fails while in service.
- Facilities-induced. Downtime caused by the facilities, such as a station roof leaking water onto the floor immediately in front of one side of the station sliding platform doors, requiring a bypass of that side of the station, or a crack in a guideway pier that limits the number of trains in an area.
- Utility-induced. Downtime caused by a utility service provider, such as the loss of an incoming electrical feed to the APM system.
- O&M-induced. Downtime caused by personnel affiliated with the O&M organization, such as the mis-operation of the system from the control center or the failure of a maintenance technician to properly isolate a piece of equipment from the active system operation on which he or she is working.
- Other. Downtime caused by other issues, such as a terrorist threat or a delay due to the transport of a VIP.

There are no provisions for partial service credit in this measure, no penalties for line capacity reductions (i.e., shorter trains), no allowances for grace periods (other than the 20-sec duration defined previously), and no penalties for unscheduled stops of trains outside stations. Nor are there exclusions for downtime events. This maintains the simplicity and usability of the measure while providing a measure most reflective of the perspective of the airport APM user.

5.3.1.2 Data Requirements and Sources

The data and sources required to calculate Service Availability (Tier A Approach) are provided in Table 5.

The location in the system where the departure times will be used as the basis for calculating Service Availability (Tier A Approach) should be where the Headway in Maximum Service occurs, as defined in Section 4.2.5. It should specifically be at a terminal station, where possible.

5.3.1.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the Service Availability (Tier A Approach) performance measure be accomplished daily, since the measure will serve a useful purpose in describing performance when reported daily within an organization.

For this measure, most of the data will typically be collected from records and systems in the control center. In some cases, the control center computer system (CCCS) that is part of the ATS subsystem will have the functionality to allow user-defined reports and/or performance measures to be generated based on custom rules set by the user, and from output data generated by the airport APM system itself. After the one-time setup of the performance measure in the CCCS, most of what is needed thereafter are the incidental updates of the causes of particular events, and perhaps not much more, depending on the sophistication of the CCCS and output data generated by the airport APM system. Control center personnel usually perform these updates after each downtime event or before their shifts are complete. In many cases, this allows reports to be automatically generated (usually daily, monthly, and/or yearly) directly by the CCCS. If this functionality exists within the CCCS, it is recommended that it be used since it could save time and effort.

Some CCCSs do not have the capability described previously but instead can dump the raw output data acquired from the airport APM system automatically to a batch file or to some other network location connected to the CCCS. This is typically done at the end of the operating day or shortly thereafter. In this case it may be easiest to import the data into a spreadsheet application having a file specifically developed to calculate and track this performance measure. The application and file could be installed on a personal computer in the control center so that staff there would have the same ability to keep the data current on each shift. It is assumed for the purpose of this guidebook and this performance measure that airport APM systems at least have the capability to retrieve departure times (with train numbers), scheduled opening and closing times, and incomplete trip information in an electronic file format from the CCCS.

Regardless of how the data are collected, some manual updates will need to be undertaken in the application for each downtime event to ensure that the measures are recorded and reported accurately. Specifically, a cause for each downtime event will need to be assigned. These causes are defined and discussed in Section 5.3.1.1. There can be one or more causes assigned to a single downtime event. For example, there may be one downtime event for the day, which was initially caused

Table 5. Data requirements and sources, Airport APM Performance Measure #1: Service Availability (Tier A Approach).

	Data	
	Requirement	**Source**
1	Actual departure times, by train number, of in-service trains from the terminal station of each route in the system	• ATS subsystem of the ATC system; typically recorded by the control center computer system (CCCS)
2	Scheduled headways, by period, and opening and closing times of the system	• ATS, CCCS
3	Location, time, and train number of trains that fail to dwell at stations on a scheduled route	• Control center logbooks • Incident reports • Work orders • ATS, CCCS
4	Location, time, and train number of trips not finished on a scheduled route	• Control center logbooks • Incident reports • Work orders • ATS, CCCS
5	Cause of downtime events	• Control center logbooks • Incident reports • Work orders

Table 6. Example reporting of airport APM Performance Measure #1: Service Availability (Tier A Approach).

	February 10, 2010		
	Day	**Month-to-Date**	**Year-to-Date**
Service Availability (Tier A Approach)	91.67%	98.00%	98.89%
	Downtime, by Category, for February 10, 2010		
	Day	**Month-to-Date**	**Year-to-Date**
Weather	3,600 sec	4,320 sec	4,320 sec
Passenger	—	4,320 sec	12,833 sec
System equipment	—	4,320 sec	9,803 sec
Facilities	—	—	—
Utility	—	—	—
O&M	3,600 sec	4,320 sec	4,500 sec
Other	—	—	7,864 sec
Total	**7,200 sec**	**17,280 sec**	**39,320 sec**

by weather, but the recovery of the system was delayed further by a technician who forgot to remove his or her red tags and locks from the breakers that allow the system to be energized and restored. This oversight extended the delay by 1 hour. If the total downtime for the event was 2 hours, then half of the downtime (3,600 sec) would be assigned to "weather" and the other half (3,600 sec) to "O&M."

To track performance over time, it is recommended that Service Availability (Tier A Approach) be calculated for the day, month, and year, with all of those measures reported daily to the hundredth of a percent (See Section 4.3.1.1). The measures reported for the month and year are always cumulative-to-date, and they reset upon the start of the new month or new year. For example, if the daily report is being issued for the 10th of February for a particular year, the reported daily measure would be for the 10th of February, the reported monthly measure would be the cumulative availability of days one through 10 of February, and the reported yearly measure would be the cumulative availability of the days from January 1st through February 10th. Downtime event causes could be reported similarly.

An example of how Service Availability (Tier A Approach) performance measures could be reported for the day of February 10, 2010, and the associated assignment of downtime are provided in Table 6, which represents a more comprehensive level of reporting for this measure. The minimum data to be reported for this measure would be as found on Form B in Exhibit A.

5.3.2 Airport APM Performance Measure #1: Service Availability (Tier B Approach)

5.3.2.1 Definition

Service Availability (Tier B Approach) is the percentage of time service has been available on the airport APM system, as defined herein. In an effort to limit the complexity of the measure and provide an alternate means of calculating service availability, the measure deliberately does not attempt to capture all system events that an airport APM user could perceive as a loss of availability. For example, actual line capacity as compared to the scheduled line capacity (in terms of train consist sizes) is not addressed by this measure. Another, headway performance, is not directly captured by this measure but may be reflected in the Service Availability (Tier B Approach) measure if a failure occurs. The service availability approaches in this and subsequent sections become more comprehensive than the Service Availability (Tier A Approach) measure by capturing a greater share of those events, and carry with them a greater level of sophistication as well.

Because service reliability (MTBF) and service maintainability (MTTR) are key components of the Service Availability (Tier B Approach) measure, they have been included in this section. Service reliability (MTBF) is the mean amount of time that the system has operated before experiencing a failure. Service maintainability (MTTR) is the mean amount of time that it has taken to restore service on the system once a failure has occurred.

Service Availability (Tier B Approach), service reliability (MTBF), and service maintainability (MTTR) are defined as:

$$SA_B = \left(\frac{MTBF_p}{(MTBF_p + MTTR_p)} \right) \times 100$$

$$MTBF = \left(\frac{SOT_p}{NF_p} \right)$$

$$MTTR = \left(\frac{\sum_{F=1}^{NF_p} TTR_F}{NF_p} \right)$$

Where:

- SA_B = Service Availability (Tier B Approach).
- MTBF = Mean time between failure = service reliability.
- MTTR = Mean time to restore = service maintainability.

- p = The represented period of time, typically the day, month-to-date, or year-to-date.
- SOT = Scheduled operating time. The total time in seconds that the system was scheduled to provide service.
- F = Failure. Failure is any of the following:
  - When any in-service train has an unscheduled stoppage during the time when the system is scheduled to provide service.
  - When any in-service train has an incomplete trip on a scheduled route during the time when the system is scheduled to provide service.
  - When any vehicle or station platform door blocks any portion of the nominal doorway opening that passengers use to board and alight trains dwelling in the station during the time when the system is scheduled to provide service.
- NF_p = Number of failures for the period. The total number of all failures in the period. (Multiple failures occurring at the same time, during the same incident, or due to the same malfunction are to be counted as one failure.)
- TTR = Total time to restore. The total time to restore service after a failure, calculated as follows:
  - For unscheduled stoppages not occurring in conjunction with a station dwell, the total time to restore begins when the train reaches zero speed and ends when the train restarts (in automatic or via manual operation).
  - For unscheduled stoppages occurring in conjunction with a station dwell, the total time to restore begins at the end of the scheduled dwell time and ends when the train departs the station. Where the unscheduled stoppage occurs during a dwell at a terminal station, and the train is taken out of service at the terminal station, the total time to restore ends when all doors of the train are closed and locked at the completion of the dwell.
  - For incomplete trips where a train fails to make a station stop on its route before arriving at its destination terminal, the total time to restore begins at the moment the train bypasses a station and ends at the start of the next station dwell for the same train.
  - For incomplete trips where a train fails to finish a trip on the scheduled route, the total time to restore begins at the moment the train ceases its trip on the route and ends at the scheduled arrival time of the trip for the scheduled destination terminal on the route.
  - For vehicle or station platform doors that block any portion of the nominal doorway opening that passengers use to board and alight trains dwelling in station, the total time to restore begins at the moment a door blocks any portion of the nominal doorway opening during the dwell and ends when the train departs the station. Where blockage of the nominal doorway opening occurs during a dwell at a terminal station, and the train is taken out of service at the terminal station, the total time to restore ends when all doors of the train are closed and locked at the completion of the dwell.

  When multiple failures occur at the same time, during the same incident, or due to the same malfunction, the total time to restore begins at the earliest start time of the failures and ends at the latest end time of the failures.
- *In-service train* is a train located in the passenger-carrying portion of the system that passengers are able to use for transport.
- *Incomplete trip* is the trip of an in-service train that fails to make a station stop on the scheduled route or that fails to finish the trip on the scheduled route.
- *Unscheduled stoppage* is the unscheduled stopping of any in-service train that is not dwelling in the station or the unscheduled stopping of any in-service train that remains in the station longer than the scheduled dwell time.

Deliberately employing operating strategies to eliminate or stop the accumulation of downtime by exploiting the intent of the rules herein, especially when those strategies do not benefit the APM user, is not permitted in the context of this system of evaluation.

All failures and total restoration times are to be quantified and assigned to one of the following predefined causal categories:

- Weather-induced. Failures caused by the weather, such as lightning striking the guideway, or a snow or ice storm.
- Passenger-induced. Failures caused by a passenger, such as a passenger holding the vehicle doors open or a passenger pulling an emergency evacuation handle on an in-service train.
- System equipment-induced. Failures caused by system equipment, such as a broken axle on an in-service train, or train control system equipment that fails while in service.
- Facilities-induced. Failures caused by the facilities, such as a station roof leaking water onto the floor immediately in front of one side of the station sliding platform doors, requiring a bypass of that side of the station, or a crack in a guideway pier that limits the number of trains in an area.
- Utility-induced. Failures caused by a utility service provider, such as the loss of an incoming electrical feed to the APM system.
- O&M-induced. Failures caused by personnel affiliated with the O&M organization, such as the mis-operation of the system from the control center or the failure of a maintenance technician to properly isolate a piece of equipment from the active system operation on which he or she is working.
- Other. Failures caused by other issues, such as a terrorist threat or a delay due to the transport of a VIP.

There are no provisions for partial service credit in this measure, no penalties for line capacity reductions (i.e., shorter trains), no allowances for grace periods, and no exclusions for failures. This maintains the simplicity and usability of the measure while providing a measure most reflective of the perspective of the airport APM user.

5.3.2.2 Data Requirements and Sources

The data and sources required to calculate Service Availability (Tier B Approach), service reliability (MTBF), and service maintainability (MTTR) are provided in Table 7.

5.3.2.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the Service Availability (Tier B Approach), service reliability (MTBF), and service maintainability (MTTR) performance measures be accomplished daily, since the measures will serve a useful purpose in describing performance when reported daily within an organization.

For these measures, most of the data will typically be collected from records and systems in the control center. In some cases, the CCCS that is part of the ATS subsystem will have the functionality to allow user-defined reports and/or performance measures to be generated based on custom rules set by the user, and output data can be generated by the airport APM system itself. After the one-time setup of the performance measures in the CCCS, most of what is needed thereafter are the incidental updates of the causes and numbers of particular failures, and perhaps not much more, depending on the sophistication of the CCCS and output data generated by the airport APM system. Control center personnel usually perform these updates after each downtime event or before their shifts are complete. In many cases, this allows reports to be automatically generated (usually daily, monthly, and/or yearly) directly by the CCCS. If this functionality exists within the CCCS, it is recommended that it be used since it could save time and effort.

Some CCCSs do not have the capability described previously, but instead can dump the raw output data acquired from the airport APM system automatically to a batch file or

Table 7. Data requirements and sources, Airport APM Performance Measure #1: Service Availability (Tier B Approach).

	Data	
	Requirement	**Source**
1	Scheduled arrival and departure times, by train number, of in-service trains at the terminal stations of each route in the system	• ATS subsystem of the ATC system; typically recorded by the CCCS
2	Actual arrival and departure times, by train number, of in-service trains at every station stop in the system	• ATS, CCCS
3	Scheduled opening and closing times of the system	• ATS, CCCS
4	Actual dwell start and end times, by train number, of all in-service trains at every station stop in the system	• ATS, CCCS
5	Location, time, and train number of trips not finished on a scheduled route	• Control center logbooks • Incident reports • ATS, CCCS
6	Times of all zero speed and non-zero speed indications for all in-service trains, by train number and location	• ATS, CCCS
7	Times and locations of in-service trains taken out of service, by train number	• Control center logbooks • Incident reports • ATS, CCCS
8	Times of all vehicle and station platform doors' closed and locked status in the system, by train number and terminal station location	• ATS, CCCS
9	Times of vehicle and station platform door opening faults, by train number and station location	• Control center logbooks • Incident reports • ATS, CCCS
10	Number of failures	• Control center logbooks • Incident reports • ATS, CCCS
11	Cause of failures	• Control center logbooks • Incident reports • Work orders • ATS, CCCS

to some other network location connected to the CCCS, for example. This is typically done at the end of the operating day or shortly thereafter. In this case it may be easiest to import the data into a spreadsheet application having a file specifically developed to calculate and track this performance measure. The application and file could be installed on a personal computer in the control center so that staff there would have the same ability to keep the data current on each shift. It is assumed for the purpose of this guidebook and performance measure that airport APM systems at least have the capability to retrieve the data described in numbers 1 through 10 of Table 7 electronically from the CCCS. If not, and if the control center manually logs all actions or events that occur throughout the operating day, then whatever information cannot be obtained electronically from the CCCS will have to be mined manually from the logbook and other locations as described in Table 7.

Regardless of how the data are collected, some manual updates will need to be undertaken in the application for each failure to ensure that the measures are recorded and reported accurately. Specifically, a cause for each failure will need to be assigned. These causes are defined and discussed in Section 5.3.2.1. There can be one or more causes assigned to a single failure. For example, there may be one failure for the day, which was initially caused by weather, but the recovery of the system was delayed further by a technician who forgot to remove his or her red tags and locks from the breakers that allow the system to be energized and restored. This oversight extended the delay by 1 hour. If the total time to restore for the event was 2 hours, then half of it (3,600 sec) would be assigned to "weather" and the other half (3,600 sec) to "O&M." Similarly, the number of failures may need to be manually updated. For example, if a train has a failed door and there is a door opening fault at every station at which the train dwells, this would need to be reflected as one failure in the application rather than as multiple failures coincident with the door opening faults at each of the stations.

To track performance over time, it is recommended that Service Availability (Tier B Approach), service reliability (MTBF), and service maintainability (MTTR) be calculated for the day, month, and year, with Service Availability (Tier B Approach) reported daily to the hundredth of a percent, and service reliability (MTBF) and service maintainability (MTTR) reported daily in hours, minutes, and seconds. The measures reported for the month and year are always cumulative-to-date, and they reset upon the start of the new month or new year. For example, if the daily report is being issued for the 10th of February for a particular year, the reported daily measures would be for the 10th of February, the reported monthly measures would be the cumulative availability of days one through 10 of February, and the reported yearly measures would be the cumulative availability of the days from January 1st through February 10th.

The number of failures and total time to restore could be reported similarly, by causal category. The example provided in Table 6 reflected downtime for the Service Availability (Tier A Approach) performance measure being reported in seconds. That could be replicated for the reporting of total time to restore under this Service Availability (Tier B Approach) performance measure, but is reported in Table 8 in hours, minutes, and seconds for the sake of comparing the two reporting units.

An example of how the Service Availability (Tier B Approach), service reliability (MTBF), and service maintainability (MTTR) performance measures could be reported for the day of February 10, 2010, and the associated assignment

Table 8. Example reporting of airport APM Performance Measure #1: Service Availability (Tier B Approach).

	February 10, 2010					
	Day		**Month-to-Date**		**Year-to-Date**	
Service Availability (Tier B Approach)	99.17%		99.88%		98.50%	
Service reliability (MTBF)	10:00:00		80:00:00		06:34:00	
Service maintainability (MTTR)	00:05:00		00:06:00		00:06:10	
	Failures and Total Time To Restore (TTR), by Category, for February 10, 2010					
	Day		**Month-to-Date**		**Year-to-Date**	
	Failures	TTR	Failures	TTR	Failures	TTR
Weather	—	—	—	—	5	03:00:00
Passenger	1	00:06:00	10	01:26:00	75	02:45:00
System equipment	1	00:04:00	8	00:30:00	30	01:30:00
Facilities	—	—	1	00:20:00	4	00:30:00
Utility	—	—	2	00:04:00	4	04:00:00
O&M	—	—	4	00:10:00	6	00:20:00
Other	—	—	—	—	1	00:46:00
Total	**2**	**00:10:00**	**25**	**02:30:00**	**125**	**12:51:00**

of number of failures and total restoration time are provided in Table 8, which represents a more comprehensive level of reporting for this measure. The minimum data to be reported for this measure would be as found on Form B in Exhibit A.

5.3.3 Airport APM Performance Measure #1: Service Availability (Tier C Approach)

5.3.3.1 Definition

Service Availability (Tier C Approach) is the percentage of time service has been available on the airport APM system, as defined herein. This availability measure, as compared to the Tier A and Tier B availability measures, is the most comprehensive among the three tiers, and also the most complex. It generally captures all events that an airport APM user could perceive as a loss of availability.

Because service mode availability, fleet availability, and station platform door availability are key components of the Service Availability (Tier C Approach) measure, they have been included in this section. Service mode availability is the fraction of the entire time the service mode has been available on the system, as defined herein. Fleet availability is the fraction of the entire time the fleet has been available in the system, as defined herein. And station platform door availability is the fraction of the entire time the station platform doors have been available in the system, as defined herein.

Service Availability (Tier C Approach), service mode availability, fleet availability, and station platform door availability are defined as:

$$SA_C = \left(\frac{\sum_{p=1}^{n} SA_{TF}}{\sum_{p=1}^{n} ST} \right) \times 100$$

$$SA_{TF} = ST \times A_{SM} \times A_F \times A_{SPD}$$

$$A_{SM} = \left(\frac{AMOT}{SMOT} \right)$$

$$A_F = \left(\frac{ACOT}{SCOT} \right)$$

$$A_{SPD} = \left(\frac{APDOT}{SPDOT} \right)$$

Where:

Service Availability (Tier C Approach)

- SA_C = Service Availability (Tier C Approach).
- SA_{TF} = Time-factored service availability value for each period.
- ST = Service time of each service period, in hours.
- p = Service period.
- n = Number of service periods.
- A_{SM} = Service mode availability.
- A_F = Fleet availability.
- A_{SPD} = Station platform door availability.

Service Mode Availability

- AMOT = Actual mode operating time. The total time, in seconds, that the system was operating in the scheduled operating mode, calculated by subtracting mode downtime from scheduled mode operating time (SMOT – MD).
- SMOT = Scheduled mode operating time. The total time, in seconds, that the system was scheduled to provide service in the specific operating mode.
- MD = Mode downtime. The total time, in seconds, of all mode downtime events.
- *Mode downtime event* is any of the following:
  – When any in-service train has an unscheduled stoppage during the time when the system is scheduled to provide service. For unscheduled stoppages not occurring in conjunction with a station dwell, the downtime begins when the train reaches zero speed and ends when the train restarts (in automatic or via manual operation). For unscheduled stoppages occurring in conjunction with a station dwell, the downtime begins at the end of the scheduled dwell time and ends when the train departs the station. Where the unscheduled stoppage occurs during a dwell at a terminal station, and the train is taken out of service at the terminal station, the downtime ends when all doors of the train are closed and locked at the completion of the dwell.
  – When any in-service train has an incomplete trip on a scheduled route during the time when the system is scheduled to provide service. For incomplete trips where a train fails to make a station stop on its route before arriving at its destination terminal, the downtime begins at the moment the train bypasses a station and ends at the start of the next station dwell for the same train. For incomplete trips where a train fails to finish a trip on the scheduled route, the downtime begins at the moment the train ceases its trip on the route and ends at the scheduled arrival time of the trip for the scheduled destination terminal on the route.

  If any of these downtime events occur at the same time or overlap one another, the earliest start time and the latest end time of the events, as defined by the rules herein, are to be used in determining downtime.
- *In-service train* is a train located in the passenger-carrying portion of the system that passengers are able to use for transport.
- *Incomplete trip* is the trip of an in-service train that fails to make a station stop on the scheduled route or that fails to finish the trip on the scheduled route.

- *Unscheduled stoppage* is the unscheduled stopping of any in-service train that is not dwelling in station or the unscheduled stopping of any in-service train that remains in station longer than the scheduled dwell time.

Fleet Availability

- ACOT = Actual car operating time. The total cumulative time, in seconds, of cars that operated within in-service trains. ACOT is calculated by subtracting car downtime from scheduled car operating time (SCOT – CD). The actual number of cars is not to exceed the scheduled number of cars for the time operated, either in the aggregate or in any vehicle/train.
- SCOT = Scheduled car operating time. The total cumulative time, in seconds, of all cars scheduled to operate within in-service trains. SCOT is calculated by multiplying the total number of cars scheduled to operate in the specific operating mode by the time, in seconds, scheduled for that mode.
- CD = Car downtime. The total time, in seconds, of all car downtime events.
- *Car downtime event* is any of the following:
  – When the car of any in-service train is not fully functional during the time when the system is scheduled to provide service. This car downtime event begins upon discovery of the event or anomaly causing a car to not be fully functional and ends when the anomaly is corrected or the train is removed from service.
  – When the car of any in-service train is not in service during the time when the system is scheduled to provide service. This car downtime event begins when the car is not able to be used for passenger transport and ends when the car is able to be used for passenger transport or when the train is removed from service.
  – When an in-service train operates with fewer than the scheduled number of cars during the time when the system is scheduled to provide service. This car downtime event begins at the time when a train with a deficient number of cars is placed in service against a schedule that requires more cars per train; it ends when either the train is removed from service or when the schedule is automatically reduced due to an operating period transition, allowing the previously deficient number of cars in the train to be sufficient.
  – When the system operates with fewer in-service trains than required by the schedule during the time when the system is scheduled to provide service. This car downtime event begins at the time the system is operated with fewer trains than required by the schedule; it ends either when the scheduled number of trains are placed into service or when the schedule is automatically reduced due to an operating period transition, allowing the previously deficient number of trains to be sufficient.

  If any of these downtime events occur at the same time or overlap one another, the earliest start time and the latest end time of the events, as defined by the rules herein, are to be used in determining downtime.
- Fully functional car. An in-service car without any anomaly that could be noticed by a passenger. For example, the failure of an HVAC unit on a hot day, restricted speed of a train due to low tire pressure, spilled coffee on the car floor, or graffiti etched into a window would all prevent a car from being fully functional. A car with an out-of-service coupler on the end of the train, a failed smoke detector, and a failed hub-o-meter are examples of anomalies that may likely go unnoticed by passengers and therefore not prevent a car from being fully functional.
- *In-service car* is a car located in the passenger-carrying portion of the system that passengers are able to use for transport.

  Where individual cars are not provided, the language in this section is to apply to vehicles. See Section 5.1.6 for definitions and discussion of car, vehicle, and train.

Station Platform Door Availability

- APDOT = Actual station platform door operating time. The total time, in seconds, that station platform doors were in service, calculated by subtracting door downtime from scheduled station platform door operating time (SPDOT – DD).
- SPDOT = Scheduled station platform door operating time. The total time, in seconds, that the station platform doors were scheduled to be in service, calculated by multiplying the scheduled number of platform doors to be in service by the time, in seconds.
- DD = Door downtime. The total time, in seconds, of all door downtime events.
- *Door downtime event* is when any station platform door does not fully open upon the arrival of an in-service train. This event begins when any station platform door does not fully open upon the arrival of an in-service train and ends when the in-service train departs. For door downtime events occurring at the same or separate platforms at the same time, the earliest start time and the latest end time of the events, as defined by the rules herein, are to be used in determining downtime.
- *In-service train* is a train located in the passenger-carrying portion of the system that passengers are able to use for transport.

Deliberately employing operating strategies to eliminate or stop the accumulation of downtime by exploiting the intent of the rules herein, especially when those strategies do not benefit the APM user, is not permitted in the context of this system of evaluation.

All downtimes are to be quantified and assigned to one of the following predefined causal categories:

- Weather-induced. Failures caused by the weather, such as lightning striking the guideway, or a snow or ice storm.
- Passenger-induced. Failures caused by a passenger, such as a passenger holding the vehicle doors open or a passenger pulling an emergency evacuation handle on an in-service train.
- System equipment-induced. Failures caused by system equipment, such as a broken axle on an in-service train or train control system equipment that fails while in service.
- Facilities-induced. Failures caused by the facilities, such as a station roof leaking water onto the floor immediately in front of one side of the station sliding platform doors, requiring a bypass of that side of the station, or a crack in a guideway pier that limits the number of trains in an area.
- Utility-induced. Failures caused by a utility service provider, such as the loss of an incoming electrical feed to the APM system.
- O&M-induced. Failures caused by personnel affiliated with the O&M organization, such as the mis-operation of the system from the control center or the failure of a maintenance technician to properly isolate a piece of equipment from the active system operation on which he or she is working.
- Other. Failures caused by other issues, such as a terrorist threat or delay due to the transport of a VIP.

There are no provisions for partial service credit in this measure, no allowances for grace periods, and no exclusions for failures. This provides a measure most reflective of the perspective of the airport APM user.

5.3.3.2 Data Requirements and Sources

The data and sources required to calculate Service Availability (Tier C Approach) are provided in Table 9.

5.3.3.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the Service Availability (Tier C Approach) performance measure be accomplished daily, since the measure will serve a useful purpose in describing performance when reported daily within an organization.

For this measure, most of the data will typically be collected from records and systems in the control center. In some cases, the CCCS that is part of the ATS subsystem will have the functionality to allow user-defined reports and/or performance measures to be generated based on custom rules set by the user, and output data can be generated by the airport APM system itself. After the one-time setup of the performance measure in the CCCS, most of what is needed thereafter are the incidental updates of the causes of particular events, and perhaps not much more, depending on the sophistication of the CCCS and output data generated by the airport APM system. Control center personnel usually perform these updates after each downtime event or before their shifts are complete. In many cases, this allows reports to be automatically generated (usually daily, monthly, and/or yearly) directly by the CCCS. If this functionality exists within the CCCS, it is recommended that it be used since it could save time and effort.

Some CCCSs do not have the capability described previously but instead can dump the raw output data acquired from the airport APM system automatically to a batch file or to some other network location connected to the CCCS. This is typically done at the end of the operating day or shortly thereafter. In this case it may be easiest to import the data into a spreadsheet application having a file specifically developed to calculate and track this performance measure. The application and file could be installed on a personal computer in the control center so that staff there would have the same ability to keep the data current on each shift. It is assumed for the purpose of this guidebook and this performance measure that airport APM systems at least have the capability to retrieve departure times (with train numbers), scheduled opening and closing times, and incomplete trip information in an electronic file format from the CCCS.

Regardless of how the data are collected, some manual updates will need to be undertaken in the application for each downtime event to ensure that the measures are recorded and reported accurately. Specifically, a cause for each downtime event will need to be assigned. These causes are defined and discussed in Section 5.3.3.1. There can be one or more causes assigned to a single downtime event. For example, there may be one downtime event for the day, which was initially caused by weather, but the recovery of the system was delayed further by a technician who forgot to remove his or her red tags and locks from the breakers that allow the system to be energized and restored. This oversight extended the delay by 1 hour. If the total downtime for the event was 2 hours, then half of the downtime (3,600 sec) would be assigned to “weather” and the other half (3,600 sec) to “O&M.”

To track performance over time, it is recommended that Service Availability (Tier C Approach) be calculated for the day, month, and year, with all of those measures reported daily to the hundredth of a percent. The measures reported for the month and the year are always cumulative-to-date, and they reset upon the start of the new month or new year. For example, if the daily report is being issued for the 10th of February for a particular year, the reported daily measure would be for the 10th of February, the reported monthly measure would be the cumulative availability of days one through 10 of February, and the reported yearly measure would be the

Table 9. Data requirements and sources, Airport APM Performance Measure #1: Service Availability (Tier C Approach).

	Data	
	Requirement	**Source**
1	Scheduled arrival and departure times, by car, vehicle, and train number, of in-service trains at the terminal stations of each route in the system	• ATS subsystem of the ATC system; typically recorded by the CCCS
2	Actual arrival and departure times, by car, vehicle, and train number, of in-service trains at every station stop in the system	• ATS, CCCS
3	System schedule, including scheduled opening and closing times of the system, scheduled start/end times of service periods, scheduled number of trains and cars or vehicles per train to be in service, and scheduled headway or departure times	• ATS, CCCS
4	Actual dwell start and end times, by car, vehicle, and train number, of all in-service trains at every station stop in the system	• ATS, CCCS
5	Location, time, and car, vehicle, and train number of trips not finished on a scheduled route	• Control center logbooks • Incident reports • ATS, CCCS
6	Times of all zero-speed and non-zero-speed indications for all in-service trains, by car, vehicle, and train number and location	• ATS, CCCS
7	Times and locations of in-service trains placed into and taken out of service, by car, vehicle, and train number	• Control center logbooks • Incident reports • ATS, CCCS
8	Number of automatic station platform doors in the system	• System description manual • Schedule
9	Times of all train and station platform doors' closed and locked status in the system, by car, vehicle, and train number, and terminal station location	• ATS, CCCS
10	Times of train and station platform door opening faults, by car, vehicle, and train number, and station location	• Control center logbooks • Incident reports • ATS, CCCS
11	Cause of failures	• Control center logbooks • Incident reports • Work orders • ATS, CCCS

cumulative availability of the days from January 1st through February 10th. Downtime event causes could be reported similarly.

Service Availability (Tier C Approach) is calculated as follows:

- First, service mode availability (A_{SM}), fleet availability (A_F), and station platform door availability (A_{SPD}) are calculated for each service period (i).
- Second, the time-factored service availability values (SA_{TF}) are calculated for each service period.
- Third, the time-factored service availability values (SA_{TF}) for all service periods to be reported upon are summed.
- Fourth, the service times (STs) of all service periods are summed.
- Fifth, Service Availability (Tier C Approach) is calculated by dividing the sum of time-factored service availability values for all service periods by the sum of service times for all service periods.

An example of how Service Availability (Tier C Approach) performance measures could be reported for the day of

Table 10. Example reporting of Airport APM Performance Measure #1: Service Availability (Tier C Approach).

	February 10, 2010								
	Day			Month-to-Date			Year-to-Date		
Service Availability (Tier C Approach)	99.27%			98.77%			99.75%		
Service mode availability	98.65%			99.74%			99.33%		
Fleet availability	98.55%			97.44%			98.65%		
Station platform door availability	98.44%			99.77%			99.67%		
	Downtime, by Availability and Category, for February 10, 2010 (in seconds)								
	Day			**Month-to-Date**			**Year-to-Date**		
	Mode	**Fleet**	**Door**	**Mode**	**Fleet**	**Door**	**Mode**	**Fleet**	**Door**
Weather	300	—	—	400	—	—	600	—	—
Passenger	—	1,100	—	—	—	—	2,000	1,100	—
System equipment	—	—	2,000	—	—	—	—	—	—
Facilities	—	—	—	—	—	—	—	—	—
Utility	—	—	—	5,000	—	—	5,000	—	—
O&M	—	—	—	—	—	500	—	—	500
Other	—	—	—	—	—	—	—	—	—

February 10, 2010, and the associated assignment of downtime are provided in Table 10, which represents a more comprehensive level of reporting for this measure. The minimum data to be reported for this measure would be as found on Form B in Exhibit A.

5.3.4 Airport APM Performance Measure #2: Safety Incidents per 1,000 Vehicle Service Miles

5.3.4.1 Definition

Safety Incidents per 1,000 Vehicle Service Miles is the rate at which safety incidents have occurred in the airport APM system. It is defined as:

$$\text{Monthly } SI_{1kvsm} = \frac{\left(\left(\sum_{d=1}^{m} SI\right) \times 1{,}000\right)}{\sum_{d=1}^{m} VSM}$$

$$\text{Yearly } SI_{1kvsm} = \frac{\left(\left(\sum_{d=1}^{y} SI\right) \times 1{,}000\right)}{\sum_{d=1}^{y} VSM}$$

Where:

- SI_{1kvsm} = Safety Incidents per 1,000 Vehicle Service Miles.
- SI = Number of safety incidents.
- *Safety incident* is an unintentional event defined as:
  - The evacuation of passengers from a train, APM station, or other public or non-public area of the APM system, regardless of whether the evacuation was attended or directed by system or life safety personnel. The removal of passengers from trains or stations for routine operations or maintenance purposes does not constitute an evacuation.
  - A mainline derailment. *Mainline* is defined as the APM guideway in the passenger-carrying portion of the system but not including mainline pocket tracks and storage and turnback/switchback tracks beyond terminals where passengers are prohibited.
  - Any incident involving damage to APM system property wherein safety was compromised during the incident or the damage compromises safety going forward. APM system property is defined as any APM system equipment within the APM system or any APM facilities and related facilities equipment within the system, such as the guideway, traction power substations, APM stations, station escalators and elevators, other APM equipment rooms, and the M&SF.
  - Any verified incident involving any person on APM system property (e.g., on a train, in an APM equipment room, in an APM station, on the guideway, at the M&SF, along the right-of-way) that resulted in injury or could have resulted in injury. *Injury* is defined as an incident that requires any medical attention, including first aid treatment.
  - Application of the emergency brake(s) on a moving in-service train in the passenger-carrying portion of the system, but not including mainline pocket tracks and storage and turnback/switchback tracks beyond terminals where passengers are prohibited.
  - The fatality of any person on APM system property (e.g., on a train, in an APM equipment room, in an APM station, on the guideway, at the M&SF, along the right-of-way).

- VSM = Vehicle service miles. *Vehicle service miles* is defined as the total miles traveled by all in-service vehicles in the system, with a vehicle being in service when located in the passenger-carrying portion of the system and when passengers are able to use it for transport (see Section 5.2.2 for further clarification).
- d = Day of the month or year, as applicable.
- m = Days in the month.
- y = Days in the year.

Safety incidents should not be double counted. For example, if all trains are evacuated as a result of a total loss of incoming power from the utility service provider, this would be recorded as one safety incident, as opposed to one safety incident per train evacuation.

When more than one of the events that define a safety incident (as described previously) occur during the same incident, the order of precedence in classifying the safety incident is as follows: (1) fatality, (2) injury, (3) evacuation, (4) mainline derailment, and (5) property damage. For example, a mainline train derails and as a result three passengers are transported to the hospital for treatment of their injuries. This is defined as a safety incident because of the mainline derailment, because of the injuries involved, and possibly because of property damage. In this case, one safety incident would be recorded as a result of the injury event.

In addition to all safety incidents being classified according to the event by which they are defined, safety incidents are also to be assigned to one of the following predefined causal categories:

- Weather-induced. Safety incidents caused by the weather, such as lightning striking the guideway, or a snow or ice storm.
- Passenger-induced. Safety incidents caused by a passenger, such as a passenger pulling an emergency evacuation handle on an in-service train.
- System equipment-induced. Safety incidents caused by system equipment, such as a broken axle on an in-service train.
- Facilities-induced. Safety incidents caused by the facilities, such as a station roof leaking water onto the floor immediately in front of the station sliding platform doors.
- Utility-induced. Safety incidents caused by a utility service provider, such as the loss of one or more incoming electrical feeds to the APM system.
- O&M-induced. Safety incidents caused by personnel affiliated with the operations and/or maintenance organization, such as the mis-operation of the system from the control center or the failure of a maintenance technician to properly isolate a piece of equipment from the active system operation on which he or she is working.
- Other. Safety incidents caused as a result of other reasons.

5.3.4.2 Data Requirements and Sources

The data and sources required to calculate Safety Incidents per 1,000 Vehicle Service Miles are provided in Table 11.

5.3.4.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the Safety Incidents per 1,000 Vehicle Service Miles performance measure be accomplished daily but be reported no more frequently than monthly since safety incidents in airport APM systems are relatively rare. In addition, the numeric value of the measure, if reported daily, could be misinterpreted to be high because the underlying basis is only 1 day's worth of vehicle service miles, as opposed to 30 days' worth of vehicle service miles in a monthly reported measure.

For this measure, most of the data will typically be collected from records and systems in the control center. Where the functionality of the CCCS and the specificity of the APM system output data allow, it may be possible to collect data for the Safety Incidents per 1,000 Vehicle Service Miles performance measure directly from the CCCS. After the one-time setup of the performance measure in the CCCS, all that may be needed thereafter are the incidental updates of classifying incidents

Table 11. Data requirements and sources, Airport APM Performance Measure #2: Safety Incidents per 1,000 Vehicle Service Miles.

	Data	
	Requirement	Source
1	Number of safety incidents and the event classifications by which they are defined	• Control center logbooks • Incident reports • Work orders • Reports and/or records of life-safety agencies
2	Vehicle service miles	• ATS, CCCS • Vehicle maintenance records
3	Cause of safety incidents	• Control center logbooks • Incident reports • Work orders

Table 12. Example reporting of Airport APM Performance Measure #2: Safety Incidents per 1,000 Vehicle Service Miles.

	February 2010											
	Month						Year-to-Date					
SI/1kVSM	0.003						0.002					
	Safety Incidents, by Category and Classification, for February 2010											
	Fatalities		Injuries		Evacuations		Mainline Derailments		Property Damage		E.B. Applications	
	Month	YTD	Month	YTD	Month	YTD	Month	YTD	Month	YTD	Month	YTD
Weather	—	—	—	—	—	—	—	—	—	—	—	—
Passenger	—	—	1	1	—	—	—	—	—	—	—	—
Sys. eqp.	—	—	—	—	—	—	—	—	—	—	—	—
Facilities	—	—	—	—	—	—	—	—	—	—	—	—
Utility	—	—	—	—	1	1	—	—	—	—	—	—
O&M	—	—	—	—	—	—	—	—	—	—	—	—
Other	—	—	—	—	—	—	—	—	—	—	—	—

as safety incidents, where appropriate, and categorizing safety incidents by cause. Control center personnel usually perform these updates after each incident or before their shifts are complete. In many cases, this allows reports to be automatically generated directly by the CCCS. It is recommended that this process be instituted if the systems and data will support it.

Other airport APM systems may have to rely on a process that is separate from the CCCS for this performance measure. For example, vehicle service miles may have to be obtained from the vehicle maintenance department, and safety incidents may have to be determined from a separate incident reporting system. If this is the case, then it is recommended that the data required for this performance measure be manually collected daily and entered in a file of a spreadsheet application containing the necessary formulas and placeholders to calculate the measure.

In some cases, the information required to determine whether an incident is a safety incident may not be readily available from data residing at the airport APM system. For example, if a passenger sustains an injury while in the system but leaves the system and then requests emergency medical assistance from airport life safety agencies while still at the airport, that information either may never be known or may only become known at a later date. In such case, the O&M organization should have some protocol in place to be able to automatically be alerted to this type of information, when available, from life safety agencies at the airport.

Regardless of how the data are collected, the safety incident will need to be classified into one of the definitions described in Section 5.3.4.1, and the cause of the safety incident will need to be assigned. As mentioned previously, this is often accomplished through manual updates, regardless of the process employed.

To track performance over time, it is recommended that Safety Incidents per 1,000 Vehicle Service Miles be calculated for the month and year, with those measures reported monthly to the thousandths. The measure reported for the year is always cumulative-to-date, and it resets upon the start of the new year. For example, if the monthly report is being issued for the month of February for a particular year, the reported monthly measure would be for the entire month of February, and the reported yearly measure would be the cumulative measure of Safety Incidents per 1,000 Vehicle Service Miles from January 1st through February 28th of that year.

An example of how Safety Incidents per 1,000 Vehicle Service Miles performance measures could be reported for the month of February 2010, and the associated classifications and categories of those incidents are provided in Table 12, which represents a more comprehensive level of reporting for this measure. The minimum data to be reported for this measure would be as found on Form B in Exhibit A.

5.3.5 Airport APM Performance Measure #3: O&M Expense per Vehicle Service Mile

5.3.5.1 Definition

O&M Expense per Vehicle Service Mile is the operations and maintenance expense for an airport APM system per vehicle service mile performed. It is defined as:

$$\text{Monthly OME}_{\text{vsm}} = \frac{\sum_{d=1}^{m} \text{OME}}{\sum_{d=1}^{m} \text{VSM}}$$

$$\text{Yearly OME}_{\text{vsm}} = \frac{\sum_{d=1}^{y} \text{OME}}{\sum_{d=1}^{y} \text{VSM}}$$

Where:

- OME_{vsm} = O&M Expense per Vehicle Service Mile.
- OME = O&M expense. *O&M expense* is the expenses associated with the operation and maintenance of the airport APM system that typically have a useful life of less than 1 year

or an acquisition cost that equals the lesser of (1) $5,000 or (2) the capitalization level established by the owner in accordance with its financial accounting practices. O&M expense includes expenses for:

– Salaries, wages, and fringe benefits. The salaries, wages, and fringe benefits expenses for all operations, maintenance, and general and administrative personnel employed to manage, operate, or maintain the airport APM system. Fringe benefits are expenses for FICA; pension plans; hospital, medical, and surgical plans; dental plans; life insurance plans; short-term disability plans; unemployment insurance; worker's compensation insurance; sick leave, holiday, vacation, and other paid absence pay; uniform and work clothing allowance; and other similar salaries, wages, and fringe benefits expenses.
– Services. The services expenses for managing, operating, or maintaining the airport APM system, or the services expenses for supporting the operation and maintenance of the system, which include expenses for management service fees; advertising fees, where applicable; professional and technical services; temporary help; contract operation and/or maintenance services; custodial services; security services; and expenses for other services.
– Materials and supplies. The materials and supplies expenses required to manage, operate, or maintain the airport APM system, which include expenses for vehicle and non-vehicle maintenance materials and supplies, administrative supplies, and expenses for other materials and supplies to operate or maintain the airport APM system.
– Utilities. The utilities expenses for operating or maintaining the airport APM system, including expenses for propulsion and system power and all other utilities expenses. Expenses for utilities not related to the operation or maintenance of the airport APM system are not to be included.
– Other. The other expenses for operating or maintaining the airport APM system, such as expenses for casualty and liability, taxes, interest expense, leases and rentals, depreciation, purchase lease payments, expense transfers, and miscellaneous expenses such as dues and subscriptions, charitable donations, and travel and meetings.

- VSM = Vehicle service miles. *Vehicle service miles* is defined as the total miles traveled by all in-service vehicles in the system, with a vehicle being in service when located in the passenger-carrying portion of the system and when passengers are able to use it for transport (see Section 5.2.2 for further clarification).
- d = Day of the month or year, as applicable.
- m = Days in the month.
- y = Days in the year.

5.3.5.2 Data Requirements and Sources

The data and sources required to calculate the O&M Cost per Vehicle Service Mile are provided in Table 13.

5.3.5.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the O&M Expense per Vehicle Service Mile performance measure be accomplished monthly and be reported no more frequently than monthly.

As with previous measures, collection of vehicle service miles data may be able to be obtained automatically from the CCCS, or, depending on the level of sophistication of the CCCS and/or output data from the airport APM system, may need to be obtained from the vehicle maintenance department.

Airport APM O&M expense data may likely be obtained from the owner of the airport APM system or the O&M services provider, and may in certain cases incorrectly include expense data not associated with the operations or maintenance of the airport APM system. The best example of this may be expenses for utility power, which may include expenses for power not associated with the operation or maintenance of the airport APM system. For example, the meters on some services serving

Table 13. Data requirements and sources, Airport APM Performance Measure #3: O&M Expense per Vehicle Service Mile.

	Data	
	Requirement	**Source**
1	Airport APM system O&M expenses, with and without utilities expenses, required for operating and maintaining the system	• Airport APM system owner's financial records and/or financial statements in its computerized accounting system • Utilities service providers billing statements • Operations and/or maintenance services provider's financial records and/or financial statements in its computerized accounting system
2	Vehicle service miles	• ATS, CCCS • Vehicle maintenance records

Table 14. Example Reporting of Airport APM Performance Measure #3: O&M Expense per Vehicle Service Mile.

	February 2010			
	Month		Year-to-Date	
	W/Utilities Expense	W/O Utilities Expense	W/Utilities Expense	W/O Utilities Expense
O&M Expense per Vehicle Service Mile	\$24.05	\$18.15	\$20.45	\$17.50

the APM may not be dedicated to only the APM services, but rather may be on a common upstream feed that branches off to the APM service and another non-APM service. In such a case, it may be difficult, if possible at all, to determine the expense for the APM service versus that of the non-APM service. In anticipation of this potential problem, it is recommended that for those systems that have dedicated meters/services, total O&M expenses be reported both with and without utilities expenses. For those systems that share services with other non-APM services, total O&M expenses should be reported without utilities expenses only.

To track performance over time, it is recommended that O&M Expense per Vehicle Service Mile be calculated for the month and year, with those measures reported monthly to the cent. The measure reported for the year is always cumulative-to-date, and it resets upon the start of the new year. For example, if the monthly report is being issued for the month of February for a particular year, the reported monthly measure would be for the entire month of February, and the reported yearly measure would be the cumulative measure of O&M Expense per Vehicle Service Mile from January 1st through February 28th of that year.

An example of how O&M Expense per Vehicle Service Mile performance measures could be reported for the month of February, 2010, is provided in Table 14, and the Airport APM Performance Measures reporting form can be found in Exhibit A as Form B.

5.3.6 Airport APM Performance Measure #4: Actual and Scheduled Capacity (Peak Versus All Other)

5.3.6.1 Definition

Actual and Scheduled Capacity (Peak Versus All Other) is the comparison of actual cumulative line capacity to scheduled cumulative line capacity for peak periods versus all other periods in an airport APM system.

Actual and Scheduled Capacity (Peak Versus All Other) is defined as:

$$SC_P = \sum_{x=A}^{n} SC_{P\_x}$$

$$SC_{AO} = \sum_{x=A}^{n} SC_{AO\_x}$$

$$AC_P = \sum_{x=A}^{n} AC_{P\_x}$$

$$AC_{AO} = \sum_{x=A}^{n} AC_{AO\_x}$$

$$SC_{P\_x} = SNT_{P\_x} \times CDC \times SNCT_{P\_x}$$

$$SC_{AO\_x} = SNT_{AO\_x} \times CDC \times SNCT_{AO\_x}$$

$$AC_{P\_x} = ANT_{P\_x} \times CDC \times ANCT_{P\_x}$$

$$AC_{AO\_x} = ANT_{AO\_x} \times CDC \times ANCT_{AO\_x}$$

Where:

- SC = Scheduled capacity. The scheduled cumulative line capacity.
- AC = Actual capacity. The actual cumulative line capacity.
- P = Peak periods.
- AO = All other periods.
- x = Train consist type (e.g., type A for a two-car train; type B for a three-car rain).
- n = Number of train consist types.
- Trip = The departure of an in-service train from the scheduled originating system terminal and arrival at the scheduled destination system terminal.
- *In-service train* is a train located in the passenger-carrying portion of the system that passengers are able to use for transport.
- SNT = Scheduled number of trips. The scheduled number of trips departing from the busiest system terminal.
- ANT = Actual number of trips. The actual number of trips departing from the busiest system terminal.
- CDC = Car design capacity. The originally specified design capacity of the car, expressed as the number of passengers per car. If this information is unavailable, then:
  - The number of passengers that can be accommodated in seats in a car (not including flip-up and stowable seats), plus

– The number of standee passengers that can be accommodated in a car based on one standing passenger for each 2.7 ft^2 of standee floor area. *Standee floor area* is defined as the area available to standing passengers, including the area occupied by flip-up and stowable seats (all non-fixed seats).
- SNCT = Scheduled number of cars per trip.
- ANCT = Actual number of cars per trip.

Where individual cars are not provided, the language in this section is to apply to vehicles. See Section 5.1.6 for definitions and discussion of car, vehicle, and train.

5.3.6.2 Data Requirements and Sources

The data and sources required to calculate Actual and Scheduled Capacity (Peak Versus All Other) are provided in Table 15.

5.3.6.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the Actual and Scheduled Capacity (Peak Versus All Other) performance measure be accomplished daily since the measure may serve a useful purpose in describing performance when reported daily within an organization. This measure might also be interesting when comparing it with the same measure for other airport APM systems, which can provide perspective on the sizes of such systems.

For this measure, most of the data will typically be collected from records and systems in the control center. In some cases, the CCCS that is part of the ATS subsystem will have the functionality to allow user-defined reports and/or performance measures to be generated based on custom rules set by the user, and output data can be generated by the airport APM system itself. After the one-time setup of the performance measure in the CCCS, most of what is needed thereafter are the incidental updates of eliminating incomplete trips, and perhaps not much more, depending on the sophistication of the CCCS and output data generated by the airport APM system. Control center personnel usually perform these updates after each downtime event or before their shifts are complete. In many cases, this allows reports to be automatically generated, usually daily, monthly, and/or yearly, directly by the CCCS. If this functionality exists within the CCCS, it is recommended that it be used since it could save time and effort.

Some CCCSs do not have the capability described previously but instead can dump the raw output data acquired from the airport APM system automatically to a batch file or to some other network location connected to the CCCS. This is typically done at the end of the operating day or shortly thereafter. In this case it may be easiest to import the data into a spreadsheet application having a file specifically developed to calculate and track this performance measure. The application and file could be installed on a personal computer in the control center so that staff there would have the same ability to keep the data current on each shift. It is assumed for the purpose of this guidebook and this performance measure that airport APM systems have the capability to provide the data requirements at least through the export of data files for use by control center and/or other personnel in their analysis and calculations of the performance measure discussed herein.

Table 15. Data requirements and sources, Airport APM Performance Measure #4: Actual and Scheduled Capacity (Peak Versus All Other).

	Data	
	Requirement	**Source**
1	Scheduled arrival and departure times, by car, vehicle, and train number, of in-service trains at the terminal stations of each route in the system	• ATS subsystem of the ATC system; typically recorded by the CCCS
2	Actual arrival and departure times, by car, vehicle, and train number, of in-service trains at terminal stations of each route in the system	• ATS, CCCS
3	System schedule, including scheduled opening and closing times of the system, scheduled start/end times of service periods, scheduled number of trains and cars or vehicles per train to be in service, and scheduled headway or departure times	• ATS, CCCS
4	Car design capacity (design loading)	• Conformed systems contract documents • Authorized official from the operating organization

Table 16. Example reporting of Airport APM Performance Measure #4: Actual and Scheduled Capacity (Peak Versus All Other) for February 10, 2010 (in total passengers).

	Day		Month-to-Date		Year-to-Date	
	Peak	All Other	Peak	All Other	Peak	All Other
Scheduled capacity	16,000	24,000	160,000	240,000	656,000	984,000
Actual capacity	15,900	22,300	156,200	220,100	648,700	909,600

To track performance over time, it is recommended that Actual and Scheduled Capacity (Peak Versus All Other) be calculated for the day, month, and year, with all of those measures reported daily and rounded to the hundreds. The measures reported for the month and the year are always cumulative-to-date, and they reset upon the start of the new month or new year. For example, if the daily report is being issued for the 10th of February for a particular year, the reported daily measure would be for the 10th of February, the reported monthly measure would be the cumulative availability of days one through 10 of February, and the reported yearly measure would be the cumulative availability of the days from January 1st through February 10th.

An example of how the Actual and Scheduled Capacity (Peak Versus All Other) performance measures could be reported for the day of February 10, 2010, is provided in Table 16, and the Airport APM Performance Measures reporting form can be found in Exhibit A as Form B.

5.3.7 Airport APM Performance Measure #5: Passenger Satisfaction

5.3.7.1 Definition

Passenger Satisfaction is the degree or level of contentment of passengers using the airport APM system and is defined as:

$$PS = \frac{\sum_{SE=1}^{NSE} MPS_{SE}}{NSE}$$

$$MPS_{SE} = \frac{\sum_{S=1}^{NS} PS_{SE}}{NS}$$

Where:

- PS = Passenger Satisfaction.
- SE = Survey element. The particular topic in the passenger satisfaction survey about which airport APM passengers are questioned, as follows:
  - 1: System availability/wait time
  - 2: Convenience/trip time
  - 3: Comfort/ride quality and cleanliness
  - 4: Ease of use/wayfinding
  - 5: Informational/announcements
  - 6: Helpfulness of staff
  - 7: Responsiveness to complaints
- NSE = Number of survey elements. The number of survey elements in the passenger satisfaction survey with a mean passenger satisfaction (MPS_{SE}) greater than 0. If any MPS_{SE} equals 0, it is not to be included in the count of NSE.
- PS_{SE} = Passenger satisfaction per survey element. The passenger satisfaction rating of a survey element on a passenger satisfaction survey.
- MPS_{SE} = Mean passenger satisfaction per survey element. The mean passenger satisfaction rating of a survey element across NS passenger satisfaction surveys.
- S = Survey. A completed passenger satisfaction survey.
- NS = Number of surveys. The number of completed passenger satisfaction surveys for a particular survey element. "Completed" means that a survey element has been given a numerical rating of 1 to 5. If a survey element has not been answered or has been answered as "N/A" or "0," then the survey element is considered incomplete and is not to be included in the count of NS.

5.3.7.2 Data Requirements and Sources

The data and sources required to calculate Passenger Satisfaction are provided in Table 17.

The sources of data for the Passenger Satisfaction measure will likely be the passenger satisfaction survey, an example of which is provided in Exhibit A, and passenger satisfaction surveyor records, which are discussed in more detail in the next section.

5.3.7.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the Passenger Satisfaction performance measure be accomplished throughout the month, with reporting of the measure upon closeout of each month.

For this measure, data can be collected using one or more of the following methods:

Table 17. Data requirements and sources, Airport APM Performance Measure #5: Passenger Satisfaction.

	Data	
	Requirement	Source
1	Date of passenger feedback	• Passenger satisfaction surveys • Passenger satisfaction surveyor records
2	Number of survey elements	• Passenger satisfaction surveys • Passenger satisfaction surveyor records
3	Number of surveys	• Passenger satisfaction surveys • Passenger satisfaction surveyor records
4	Numerical rating of each survey element	• Passenger satisfaction surveys • Passenger satisfaction surveyor records

- Forms. Survey forms, as provided in Exhibit A, should be reduced to a postcard size and be readily available to airport APM passengers on the trains, in the stations, and in other high-circulation areas where airport APM passengers will pass by or wait. Secure drop boxes should be well-placed in stations or similar areas to allow passengers to return the completed surveys with ease. Addresses should be preprinted on the opposite side of the card to allow passengers to return the surveys by U.S. postal mail as well. Survey forms may be the most cost-effective method to obtain data for the Passenger Satisfaction measure, and therefore are likely to be the most commonly used.
- Face-to-face contact. Employing the use of a subcontractor, or employees of the airport or the APM O&M organization, is another method that can be used to obtain Passenger Satisfaction data. The surveyor(s) can be posted at a station and ask alighting (rather than boarding) airport APM passengers to rate their satisfaction for the survey elements provided in Exhibit A. This data collection method can be costly if performed on a regular basis but likely is the best way to obtain objective feedback. It may also be the best way to obtain the greatest quantities of feedback, thereby providing greater confidence in the overall Passenger Satisfaction performance measure.
- Phone-in. The phone-in survey method could be a convenient way of collecting data from passengers because of the popularity and common use of cellular telephones. A toll-free number could be posted throughout the airport APM system inviting passengers to phone in their perceptions of their experience using the system. The survey elements could be collected via a system where passengers listen to the questions then provide their single-digit numerical rating when prompted. At the end of the survey, passengers could leave a voicemail, if desired. This method, although convenient for both passengers and the organization collecting the data, could be costly, at least possibly for the initial investment in the telephone/computer system that would manage this effort.
- Email/Internet. The email/Internet survey method is similar to the phone-in survey method in that an email or web address could be posted at various locations in the airport APM system inviting passengers to complete the survey form via email or directly in a web browser via the Internet. Passengers could again likely use their cell phones via this method, which makes it a convenient method for both the passenger and organization collecting the data. It could even prove to increase the response rate as compared to other methods. In addition, this method would likely be appreciably more cost effective than the phone-in or face-to-face methods, thereby making it one of the more attractive options.

The primary difference between these data collection methods is that feedback occurs only upon the initiative of the passenger under the forms, phone-in, and email/Internet methods, whereas for the face-to-face method, feedback occurs upon the initiative of the data collection organization through interactive, one-on-one contact. If an organization relies solely on obtaining feedback via methods dependent only on the passengers' initiative, the Passenger Satisfaction measure could be more representative of passenger dissatisfaction since it could be assumed that passengers might be more motivated to provide feedback when encountering a bad experience than an expected or good experience. Under this premise, it is recommended that organizations at a minimum collect 10 surveys per month (approximately 2 to 3 per week) using an employee, for example, to elicit and record responses to survey elements via face-to-face contact with passengers. It is also recommended that a permanent, continuous data collection method be implemented using one of the other methods listed previously to acquire as much feedback on passenger satisfaction performance for the airport APM system as possible. The more surveys that have been completed for the month via both of these methods, the more confidence there can be that the Passenger Satisfaction performance measure is generally representative for all measures of passenger satisfaction.

The calculation of the Passenger Satisfaction measure is to be accomplished using the numerical ratings of the survey elements assigned by the passengers. The numerical rating value of survey element number one, for example, is summed across all surveys and then divided by the number of those surveys to obtain the mean passenger satisfaction for that survey element. The same is done for all other survey elements. Then, the mean passenger satisfaction values for the survey elements are summed and divided by the number of survey elements to obtain the representative value for the Passenger Satisfaction measure. When any of the survey elements or mean passenger satisfaction values are 0, they are not included in the number of surveys or survey elements in the divisor. This avoids an undue penalty for a question left blank or a "do not know" response.

To track performance over time, it is recommended that Passenger Satisfaction be calculated for the month and year, with those measures reported monthly to two decimal places. Passenger Satisfaction for the month would reset at the conclusion of each month, and Passenger Satisfaction for the year would be reported monthly as year-to-date and reset at the conclusion of the year. Care should be exercised in reporting Passenger Satisfaction measures more frequently than monthly (i.e., month-to-date in conjunction with a daily report, for example) unless at least 10 surveys have been collected via face-to-face contact. The goal is ultimately to provide reporting on the measure that reflects a significant enough survey sample size without overburdening the organization responsible for collecting that data.

The data collected for the Passenger Satisfaction measure could be further analyzed by calculating standard deviation or plotting histograms, which can identify problems not recognized through monthly reporting of a numerical value, such as the mean passenger satisfaction measure set forth herein.

An example of how Passenger Satisfaction and mean passenger satisfaction for each survey element could be reported for the month of February 2010 is provided in Table 18, which represents a more comprehensive level of reporting for this measure. The minimum data to be reported for this measure would be as found on Form B in Exhibit A.

5.3.8 Airport APM Performance Measure #6: Missed Stations per 1,000 Station Stops

5.3.8.1 Definition

Missed Stations per 1,000 Station Stops is the rate at which missed stations have occurred in the airport APM system. It is defined as:

$$\text{Monthly } MS_{1kss} = \frac{\left(\left(\sum_{d=1}^{m} MS\right) \times 1{,}000\right)}{\sum_{d=1}^{m} SS}$$

$$\text{Yearly } MS_{1kss} = \frac{\left(\left(\sum_{d=1}^{y} MS\right) \times 1{,}000\right)}{\sum_{d=1}^{y} SS}$$

Where:

- MS_{1kss} = Missed Stations per 1,000 Station Stops.
- MS = Number of missed stations.
- *Missed station* is when an in-service train either does not stop at a station on the scheduled route or stops at a station on the scheduled route in the following manner:
  - The train overshoots the station, resulting in either no doors opening, some doors opening, or all doors opening but misaligned by 6 in. or more.
  - The train stops short of the station, resulting in either no doors opening, some doors opening, or all doors opening but misaligned by 6 in. or more.
- SS = Station stops. *Station stops* is defined as the total number of station stops in-service trains are scheduled to make for the specified operating mode. For example, if due to

Table 18. Example reporting of Airport APM Performance Measure #5: Passenger Satisfaction.

	Passenger Satisfaction	
	Month	**Year-To-Date**
February 2010	4.30 = High	4.00 = High
	Mean Passenger Satisfaction, by Survey Element February 2010	
	Month	**Year-To-Date**
System availability/wait time	4.00	3.25
Convenience/trip time	3.50	3.25
Comfort/ride quality/cleanliness	4.00	4.00
Ease of use/wayfinding	5.00	4.25
Informational announcements	5.00	4.25
Helpfulness of staff	0.00	5.00
Responsiveness to complaints	0.00	0.00
0–2.44 = Low passenger satisfaction 2.45–3.44 = Medium passenger satisfaction 3.45–5.00 = High passenger satisfaction		

Table 19. Data requirements and sources, Airport APM Performance Measure #6: Missed Stations per 1,000 Station Stops.

	Data	
	Requirement	**Source**
1	Number of missed stations	• ATS, CCCS • Control center logbooks • Incident reports • Work orders
2	Station stops, determined from individual station arrival and departure times, by train number, for example	• ATS, CCCS • Control center logbooks (start/stop time of failure modes) • Incident reports (start/stop time of failure modes)

failure the system operation is changed from the nominal pinched-loop mode to a failure mode, such as a runaround (single tracking around a failed area), then station stops would be calculated based on the stops scheduled to be made on the pinched loop for the time operating in that mode and based on the stops scheduled to be made on the runaround for the time operating in that mode.

- *In-service train* is a train located in the passenger-carrying portion of the system that passengers are able to use for transport.
- d = Day of the month or year, as applicable.
- m = Days in the month.
- y = Days in the year.

5.3.8.2 Data Requirements and Sources

The data and sources required to calculate Missed Stations per 1,000 Station Stops are provided in Table 19.

5.3.8.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the Missed Stations per 1,000 Station Stops performance measure be accomplished daily but be reported no more frequently than monthly since missed stations in airport APM systems are relatively rare. In addition, the numeric value of the measure, if reported daily, could be misinterpreted to be high because the underlying basis is only 1 day's worth of stations stops, as opposed to 30 days' worth of station stops in a monthly reported measure.

For this measure, most of the data will typically be collected from records and systems in the control center. Where the functionality of the CCCS and the specificity of the APM system output data allow, it may be possible to collect data for the Missed Stations per 1,000 Station Stops performance measure directly from the CCCS. After the one-time setup of the performance measure in the CCCS, all that may be needed thereafter are the incidental updates of classifying incidents as missed stations, where appropriate. Control center personnel usually perform these updates after each incident or before their shifts are complete. In many cases, this allows reports to be automatically generated directly by the CCCS. It is recommended that this process be instituted if the systems and data will support it.

Other airport APM systems may have to rely on a process that is separate from the CCCS for this performance measure. For example, missed stations may have to be obtained from a logbook or station stops manually determined from the operating schedule. If this is the case, then it is recommended that the data required for this performance measure be manually collected daily and entered in a file of a spreadsheet application containing the necessary formulas and placeholders to calculate the measure.

To track performance over time, it is recommended that Missed Stations per 1,000 Station Stops be calculated for the month and year, with those measures reported monthly to the thousandths. The measure reported for the year is always cumulative-to-date, and it resets upon the start of the new year. For example, if the monthly report is being issued for the month of February for a particular year, the reported monthly measure would be for the entire month of February, and the reported yearly measure would be the cumulative measure of Missed Stations per 1,000 Station Stops from January 1st through February 28th of that year.

An example of how the Missed Stations per 1,000 Station Stops performance measure could be reported for the month of February 2010 is provided in Table 20, and the Airport

Table 20. Example reporting of Airport APM Performance Measure #6: Missed Stations per 1,000 Station Stops.

	February 2010	
	Month	**Year-to-Date**
Missed Stations per 1,000 Station Stops:	0.003	0.002

APM Performance Measures reporting form can be found in Exhibit A as Form B.

5.3.9 Airport APM Performance Measure #7: Unintended Stops per 1,000 Interstations

5.3.9.1 Definition

Unintended Stops per 1,000 Interstations is the rate at which unintended stops have occurred outside of stations in the airport APM system. It is defined as:

$$\text{Monthly } US_{1ki} = \frac{\left(\left(\sum_{d=1}^{m} US\right)\times 1{,}000\right)}{\sum_{d=1}^{m} I}$$

$$\text{Yearly } US_{1ki} = \frac{\left(\left(\sum_{d=1}^{y} US\right)\times 1{,}000\right)}{\sum_{d=1}^{y} I}$$

Where:

- US_{1ki} = Unintended Stops per 1,000 Interstations.
- US = Number of unintended stops.
- *Unintended stop* is the stopping of an in-service train in a location outside of a station where the train does not normally stop as part of the nominal system operation.
- I = Interstations. *Interstations* is defined as the total number of interstations traveled by all in-service trains, with one interstation being the directional segment between two adjacent stations in the system. For example, a train operating from stations A to D in Figure 6 would travel two interstations (A to C and C to D); an in-service train operating a round trip on a two-station shuttle system would travel two interstations.
- *In-service train* is a train located in the passenger-carrying portion of the system that passengers are able to use for transport.
- d = Day of the month or year, as applicable.
- m = Days in the month.
- y = Days in the year.

5.3.9.2 Data Requirements and Sources

The data and sources required to calculate Unintended Stops per 1,000 Interstations are provided in Table 21.

5.3.9.3 Data Collection Techniques and Calculating and Recording the Measure

It is recommended that the collection of data for the Unintended Stops per 1,000 Interstations performance measure be accomplished daily but be reported no more frequently than monthly since unintended stops in airport APM systems may not occur frequently. In addition, the numeric value of the measure, if reported daily, could be misinterpreted to be high because the underlying basis is only 1 day's worth of interstations traveled as opposed to 30 days' worth of interstations traveled in a monthly reported measure.

For this measure, most of the data will typically be collected from records and systems in the control center. Where the functionality of the CCCS and the specificity of the APM system output data allow, it may be possible to collect data for the Unintended Stops per 1,000 Interstations performance measure directly from the CCCS. In many cases, this allows reports to be automatically generated directly by the CCCS. It is recommended that this process be instituted if the systems and data will support it.

Other airport APM systems may have to rely on a process that is separate from the CCCS for this performance measure and/or export and analysis of data from the CCCS. If this is the case, then it is recommended that the data required for this performance measure be manually or automatically collected daily and entered in a file of a spreadsheet application containing the necessary formulas and placeholders to calculate the measure.

To track performance over time, it is recommended that Unintended Stops per 1,000 Interstations be calculated for the month and year, with those measures reported monthly to the thousandths. The measure reported for the year is always cumulative-to-date, and it resets upon the start of the new year. For example, if the monthly report is being issued for the

Table 21. Data requirements and sources, Airport APM Performance Measure #7: Unintended Stops per 1,000 Interstations.

	Data	
	Requirement	Source
1	Number of unintended stops	• ATS, CCCS • Control center logbooks • Incident reports
2	Interstations, determined from origin terminal departure times, by train number, and destination terminal arrival times, by train number, for example	• ATS, CCCS

Table 22. Example Reporting of Airport APM Performance Measure #7: Unintended Stops per 1,000 Interstations.

	February 2010	
	Month	Year-to-Date
Unintended Stops per 1,000 Interstations	0.003	0.002

month of February for a particular year, the reported monthly measure would be for the entire month of February, and the reported yearly measure would be the cumulative measure of Unintended Stops per 1,000 Interstations from January 1st through February 28th of that year.

An example of how the Unintended Stops per 1,000 Interstations performance measure could be reported for the month of February 2010 is provided in Table 22, and the Airport APM Performance Measures reporting form can be found in Exhibit A as Form B.

CHAPTER 6

Other Airport APM System Performance Measures

This guidebook has been provided to identify a set of performance measures and associated data requirements for airport APM operators to assess and improve performance, compare airport APM systems, and plan and design future systems. The measures are intended to address the efficiency, effectiveness, and quality of APM systems at airports.

Thus far, the guidebook has set forth the measures to be used in comparing airport APM systems (i.e., external measures). These measures can also be used to assess and improve the performance of an individual airport APM system and, therefore, can be used as internal measures as well. However, there are other internal measures that may be useful for assessing and improving the performance of an individual airport APM system that do not work as well as external measures. The following sections discuss these additional internal measures as well as those to be used in the planning and design of airport APM systems.

6.1 Internal Measures for Assessing and Improving Performance of Airport APM Systems

Airport APM systems have varying characteristics and are made up of different technologies that can make it challenging to develop meaningful measures that are directly comparable among airport APM systems. Chapter 5 set forth the measures that may be the best in achieving such comparisons. However, there are many other performance measures that can be implemented by airport APM systems and that may be worthwhile to track for assessing and improving the internal performance of an individual airport APM system even though they may not be worthwhile for comparisons among systems.

Some of the internal measures currently in use or that could be implemented at airport APM systems are:

- Average vehicle service miles per collector shoe;
- Average vehicle service miles per traction motor;
- Average vehicle service miles per running tire;
- Average vehicle service miles per guidance tire;
- Average cycles per drive cable (for cable-propulsion APMs);
- MTBF or MTTR, ATC system:
  - MTBF or MTTR, automatic train operation (ATO) subsystem;
  - MTBF or MTTR, ATS subsystem;
  - MTBF or MTTR, ATP subsystem;
  - MTBF or MTTR, traction power distribution system; and
  - MTBF or MTTR, guideway equipment system.

The purpose of this chapter is not to provide a comprehensive list or detailed definition and requirements for these measures; rather it is to illustrate that the number and type of performance measures that could be implemented for internal measurement purposes are quite extensive.

Although operators of an airport APM system may choose to implement numerous performance measures, an effective performance measurement program should reflect a balanced set of a few vital measures (see Section 4.2). More often than not, airport APM system owners/operators implement these few vital measures to represent performance of the entire system, but individual departments within the O&M organization will often track many other measures directly related and helpful to their discipline. Sometimes this involves the temporary establishment of a performance measure due to an abnormally high failure rate of a particular component that may not have otherwise been the target for such a measure. For example, the vehicle maintenance department may be interested in understanding the wear rate of running tires so as to compare one manufacturer to another, or in understanding why there are higher wear rates at a given time (e.g., there could be a track condition causing this higher wear). Or, there may be a component on an electronic circuit board failing in relatively large numbers after operating without incident for a number of years. In this case, implementing a performance measure associated with this component would be expected for a certain period until the cause is identified and rectified, but it would likely be a measure that would not have otherwise been implemented nor permanently instituted had the spike in failures not have occurred.

6.2 Measures for Planning and Designing Airport APM Systems

APMs play a critical role in transporting passengers efficiently and safely at airports and therefore need to be highly dependable and safe. The measures that can be used for planning and designing airport APM systems largely include the availability-, reliability-, and maintainability-type measures similar to those discussed in previous sections of the guidebook. For example, during the planning and design phases of an airport APM system, APM system suppliers determine the dependability, availability, reliability, and/or maintainability values of subcomponents, equipment, and subsystems, based on certain anticipated failure rates, to verify that the overall system will meet the target of the particular performance measure once service is established. Often, these targets are stringent due to the critical role APM systems play at airports.

When planning APMs, such high performance standards can be considered in developing alignments and configurations that will allow APM system suppliers to provide the equipment and equipment redundancies necessary to ensure that the system will perform at these levels. For example, there could be several crossovers in an airport APM system that allow APM vehicles to operate around a failed section of track and still move passengers among airport facilities fairly efficiently. The consideration of crossover quantities and placement during the planning and design phases of an airport APM system is driven, in part, by satisfying the high targets set for these service availability performance measures.

Similarly, certain airport APM systems have the capability to automatically couple APM vehicles into larger train consists and immediately insert these trains into service to rapidly respond to either increased demand in the system or to degraded operational modes brought on by one or more mainline failures. This automated coupling feature, along with the crossover quantity/placement issue mentioned previously, can allow a system to be rapidly reconfigured and maintain the same line capacity in a degraded operational mode as in nominal operational modes. The consideration of this feature in the planning and design phases of an airport APM is again driven, in part, by satisfying the high targets set for the availability performance measures.

Safety is also extensively considered in the planning and design of airport APM systems, and performance measures are used to quantify and verify during the design phase that hazards are limited to essentially negligible levels. For example, the mean time between hazard element (MTBHE) performance measure is used, in part, to verify and validate that the duration of time between hazard elements for the ATC system meets or exceeds the required level.

Other measures that can be considered during the planning and design of an airport APM system include the walk distance to airport APM stations, number of level changes to and from the APM station, the APM platform size and configuration [i.e., center platform, side platforms, triple (flow-through) platforms, etc.], ultimate design line capacity of the system, travel time, and passenger vehicle space allocations. These are discussed in *ACRP Report 37: Guidebook for Planning and Implementing Automated People Mover Systems at Airports.*

CHAPTER 7

Implementing an Airport APM Performance Measures Program

The previous chapters of this report have established a methodology for tracking, calculating, and recording performance measures for APM systems at airports. By standardizing the data requirements and computational methods for these measures, it is expected that measurement data prepared for different APM systems would be directly comparable. If that is so, then such data would be of great benefit to airport APM operators, airport administrators, airport APM planners, APM system manufacturers, and other interested parties, provided that a program is established for collecting and disseminating the information. Having such information widely available would advance the APM industry and make it even more effective in solving the transportation issues that will continue to exist at airports in the future as passenger traffic continues to grow. Thus it is worthwhile at this juncture to identify and discuss some of the issues that may be involved with establishing a program for collecting and disseminating airport APM performance data, which is the primary subject of this chapter. Before getting into the discussion of implementing a national-level program, however, the following section addresses the implementation of an airport APM performance measures program at the local level—that is, for an individual airport APM system.

7.1 Implementing an Airport APM Performance Measures Program for an Airport APM System

Implementing an airport APM performance measures program at the local level—for an individual airport APM system—is straightforward and involves the collection, tracking, calculation, and reporting of performance measures and related data to interested individuals for the particular airport APM system. In the context of implementing the program at the local level, data for the system and service descriptive characteristics do not necessarily need to be tracked, collected, calculated, or reported since these are largely used to provide context to the airport APM performance measures once said measures are used for comparison purposes against other airport APM systems.

While the initial setup of the performance measures program may need the involvement of an IT staff member to automatically extract ATS data from the control center computer system, in many cases control center personnel will thereafter collect, track, calculate, compile, and report the performance measures in accordance with the rules and frequencies discussed in Chapter 5 and using (if needed) the tools provided as a download with this guidebook from the summary page for *ACRP Report 37A* at http://www.trb.org/Main/Blurbs/166387.aspx, as well as the forms in Exhibit A. As many airport APM systems operate many hours per day, into the night, and even 24 hours per day, control center staff, who are required to be on duty whenever the system is operating, often are ideal candidates to be responsible for the performance measures program. The daily report can be prepared by the control center staff early in the morning for the previous day's operation, reflecting all of the performance measures and associated data relevant to the organization, and be available to the organization's general manager first thing in the morning. Performance measure reports should be posted in a conspicuous location for the entire organization to view, which provides employees with a sense of accomplishment that their contribution in the organization is ultimately recognized through stable and/or improving performance measures.

The following sections discuss implementation of an airport APM performance measures program at a level that will allow multiple airport APM systems to report, share, and compare performance measures data on a regular basis.

7.2 Administrative and Funding Issues

It is important to note the differences in the airport APM industry and the urban transit industry in the United States. (Note: While this discussion focuses on United States APM and urban transit systems, similar jurisdictional issues exist in Canada and throughout North America.)

Urban transit systems in the United States typically receive some level of federal financial support for capital construction and expansion. Because of this, the federal government is able to (and does) impose requirements on the funding recipients to collect and report system performance data on an annual basis. The result is the National Transit Database (NTD). This database contains a wealth of data and information that are collected and reported by transit operating properties throughout the United States. It is available free to the public at http://www.ntdprogram.gov. The information is substantial and comprehensive and is thus very useful to transit planners, administrators, and owner/operators.

However, the information comes at a price: to the transit owners/operators, the price is the cost of collecting, organizing, and reporting the data. [In most cases, additional employee(s) are required at the transit properties to deal with this reporting requirement. There are classes taught periodically around the United States to educate and train transit representatives in the specifics of this job.] To the federal government, the cost is the administrative organization required to process the reported data and ensure its availability to the public. In short, because of the leverage gained by funding urban transit systems, the federal government has been able to establish and perpetuate a program of urban transit performance information.

This is not the case with the airport APM industry. With rare exceptions, airport APM systems are constructed and operated with local funding. Therefore, the leverage used by the federal government to establish the National Transit Database for urban transit systems does not exist in the airport APM arena. Furthermore, there is no central authority that has jurisdiction over the operational and safety issues of airport APM systems. While the FTA, through enacted legislation, mandates that individual states oversee the safety of the transit systems in their states, it is left up to the individual states to decide whether airport APM systems are included in this mandate. In cases where a state determines that airport APMs are included, state representatives perform safety audits and other oversight activities on the airport systems in accordance with the regulations promulgated by the FTA. Some states do this, but most do not. In summary, virtually all airport APM systems in the United States are constructed, owned, and operated by local entities—airport authorities and/or cities—without federal involvement. This presents a considerable obstacle to implementing a national (or North American) program for collecting and disseminating airport APM performance data.

Similar issues arise when considering the funding that would be required to implement a nationwide program. Quite simply, no central funding source is apparent. Furthermore, even if there were a central funding source, persuading legislators and/or administrators to allocate scarce resources to a new program of this type, in today's financial environment, seems unlikely.

For these reasons, a logical conclusion at this time is that implementation of a nationwide airport APM performance measurement program would have to begin on a voluntary basis. This conclusion serves as a basis for the following discussions in Section 7.3, Airport Participation Issues, and Section 7.4, Data Collection and Reporting Issues.

7.3 Airport Participation Issues

If one accepts the previous conclusion that an airport APM performance data collection and reporting program will have to be (at least started) on a voluntary basis, then the central question that must be addressed is: Why would an airport APM operator want to participate and thereby incur the attendant costs? And the most obvious answer is that participation is perceived by the operator as in some way enlightening and/or benefitting its operational activities. The program must be organized and implemented with this goal clearly in focus.

And how would participation in a performance measuring program benefit an airport APM operator? Perhaps by providing the operator with:

- Quantitative system information to enforce internal contractual requirements (in cases where O&M activities are performed by contract entities),
- Quantitative system information to support internal requests for funding,
- Quantitative information to be used in discussions with airport airlines and tenants,
- Comparative information about other systems in order to assess relative performance levels achieved,
- Comparative information about other systems to establish goals for improving and/or modifying performance and costs in order to optimize system operation and service levels, or
- Comparative information about other systems to persuade airlines and/or airport tenants of the efficacy of choosing (or remaining at) the airport.

In short, knowledge is power and competition is motivational. A voluntary program for collecting, reporting, and exchanging airport APM performance data would have to be designed and promoted on this basis. Practically speaking, such a program would have to be sold. A primary, initial task of the sponsoring agency or association would be to recruit participants. Person-power, money, and time would have to be devoted to contacting candidate airports, explaining the program, and convincing the airport of the benefits of (voluntary) participation.

In addition to issues related to the collection and reporting of data, there are issues surrounding the compilation and dissemination of the data. As noted previously, there is no readily apparent central agency to perform this task. It is therefore reasonable to ask what other entities might exist that could assume that responsibility. (Again, with the stipulation that no funding source has yet been identified.) The following candidates might be considered:

- Airport industry associations. There are several associations of airport industry firms and individuals that are active in the United States and North America. All of these associations receive dues from their members and therefore (presumably) have some (no doubt limited) funds for discretionary spending. It is possible that one of these associations might be persuaded to sponsor a program for quantifying airport APM performance. Candidate associations include:
  – Airports Council International–North America (ACI-NA). This group represents airport owners/operators and includes most of the largest airports in North America, many of which own and operate airport APMs. This is the largest of the associations noted here, and it has institutional funding. It is possible that ACI-NA would consider sponsoring an APM performance measuring program.
  – American Association of Airport Executives (AAAE). Members of this group are typically individual executives working at various airports, large and small. Their involvement with airport APM systems has historically been limited.
  – Airport Consultants Council (ACC). ACC is an association of private firms doing business with airports and includes many of the largest architectural and engineering consultants in the world. Many of these firms have intimate involvement with the planning, implementation, and operation of airport APMs and might possibly see an advantage in sponsoring an airport APM performance measuring program, at least initially.
- ASCE APM Standards Committee. The ASCE APM Standards Committee has become the single most influential organization in the United States with respect to standardizing requirements for airport APM systems. A voluntary group of industry professionals, owner/operators, manufacturers, and suppliers, this committee was established to consider and promulgate standard requirements applicable to the design, implementation, and operation of airport APM systems. The ASCE APM Standards Committee has the expertise to administer an APM data program; however, it has (at present) minimal funding and relies entirely on volunteer staffing.
- University research. There are many North American universities that offer specialized education in many areas of transportation, including airports. It is possible that a university group or class, organized and sponsored by an interested faculty member, might be willing to take on this assignment, perhaps just for the start-up phase. However, funding would probably be an issue.

The previous items are suggestions that might be explored further in an effort to continue the work and benefits of this guidebook.

7.4 Data Collection and Reporting Issues

As with any complex undertaking, establishing an airport APM performance reporting program would require identifying and resolving many detailed issues associated with the data itself. Some of these issues are:

- Legal agreements. The program as envisioned would involve collecting, pooling, and potentially distributing data that is owned by, and proprietary to, the APM-operating airports. Would this require a legal framework and agreements between the airports and sponsor governing the handling and use of the resulting information? This concern would especially apply to financial data.
- Election of Service Availability Approach Tier A, B, or C. This guidebook envisions three levels of participation for the Service Availability measure, each progressively requiring more work but providing greater return. A primary consideration for an airport considering participating in the program would be which tier to implement. Consideration would involve assessing resources currently in place, prospects for more resources, and the airport's assessment of the benefits attendant with each tier. It would be beneficial, even necessary, for a sponsoring agency representative to advise the airport on this choice.
- Procedures. What form would the reporting process take? As noted elsewhere in this guidebook, many of the larger airport APM systems already collect performance information automatically, as a function of the system's central control. Would that data simply be downloaded to disk and sent to the sponsor? Would formatting issues have to be worked out to allow aggregation by the sponsor? Would common forms be required for airports that do not collect information automatically, or would they just send in copies of their logs and records to be processed by the sponsor?
- Frequency. How frequently would data be submitted for processing?

- Availability. To whom would the data be available? This would obviously have to be spelled out in any legal agreement(s) between the participants. An argument can be made that the data should only be available to the airports that participate in the program. In a broader sense, however, the industry would garner more benefits if the data were available to a larger community of professional airport planners, operators, and even system manufacturers.
- Scope. What airports would be able to participate? Although this report has focused on North American airports, there are many airport APM systems not located on this continent. The industry would benefit from their inclusion—would they be allowed?
- Authority and control. Contemplating the issues raised previously makes it apparent that many decisions would have to be made in the course of the program, both to ensure it was implemented in accordance with the objectives of this guidebook and to ensure that the program grows and evolves in the most expeditious and beneficial way. Who has the authority to make such decisions? Would the sponsor have complete authority, or would the sponsor answer to an industry group (like the ASCE APM Standards Committee) that would approve significant policy and operational decisions?

7.5 Conclusions

The preceding sections posed many questions, not as impediments to implementing an airport APM performance measures program but as reasonable challenges. As noted throughout this report, the benefits of such a program would be myriad and worthwhile. If it were easy, it would have already been done. The APM industry is now mature and is destined to play a central role in the growth of airports for years to come. That prospect should motivate industry participants to recognize the potential benefits of an airport APM performance measures program and rise to these challenges.

Bibliography

American Society of Civil Engineers. Automated People Mover Standards—Part 1. Reston, VA: American Society of Civil Engineers, 2006.

Anderson, J. E. "Dependability as a Measure of On-Time Performance of Personal Rapid Transit Systems." *Journal of Advanced Transportation,* 26, 1992, Institute for Transportation, Inc.

Chang, H. W., R. D. Banker, and W. W. Cooper. "Simulation Studies of Efficiency and Returns to Scale with Nonlinear Functions in DEA," *Annals of Operations Research,* 1995.

Charnes, A., W. Cooper, and E., Rhodes. "Measuring the Efficiency of Decision-Making Units." *European Journal of Operational Research,* 1978.

Chicago O'Hare International Airport. AGT System Technical Provisions. Undated.

Chicago O'Hare International Airport. How to Count the Availability. 1993.

Chu, X., G. J. Fielding, and B. W. Lamar. "Measuring Transit Performance Using Data Envelopment Analysis." California University, Irvine, 1990.

Cottrell, W. D., and Y. J. Nakanishi. "Airport APM Performance Measurement: Network Configuration and Service Availability." 11th International Conference on Automated People Movers, Apr. 2007, American Society of Civil Engineers. Vienna.

Dallas–Fort Worth International Airport. APM System Operations and Maintenance General Conditions (Conformed), November 2000.

Elms, C. P. "Defining and Measuring Service Availability for Complex Transportation Networks." International Conference on PRT & Other Emerging Transportation Systems, Nov. 1996. Minneapolis.

Federal Highway Administration, Office of Operations. Performance Measurement Fundamentals. http://ops.fhwa.dot.gov/perf_measurement/fundamentals.htm. Accessed October 2007.

Frey, H., and A. Levy. An Incentive Approach to Contractual Availability for Downgraded Operation. 9th International Conference on Automated People Movers, Sept. 2003, ALONEX/Aeroports de Paris. Singapore.

Gosling, G. D., and L. Xiao-Yun. "Modeling Measures to Improve Intermodal Connectivity At Airports." University of California at Berkeley, 2006.

Government Accountability Office. *Performance Measurement and Evaluation: Definitions and Relationships.* GAO-05-739SP. 2005.

Greater Orlando Aviation Authority, Orlando International Airport. Phase II Expansion, Automated Guideway Transit System, Part 4—O&M Contract Provisions. 1987.

Henderson, G., P. Kwong, and H. Adkins. "Regularity Indices for Evaluating Transit Performance." Transportation Research Record 1297. TRB, National Research Council, Washington, D.C., 1991, pp. 3–9.

Howell, J. K. "RAM: Reliability, Availability, and Maintainability of APM Systems." 2nd International Conference on Automated People Movers, March 1989, American Society of Civil Engineers. Miami.

Kaplan, R., and D. Norton. "The Balanced Scorecard: Measures that Drive Performance." *Harvard Business Review.* Vol. 70, Issue 1 (Jan/Feb 1992), pp. 71–79.

Lee, D. B. "Transit Cost and Performance Measurement." *Transport Reviews,* Vol. 9, No. 2. Taylor & Francis Limited, 1989.

Lede, N. W., and L. Yu. *A Manual for Evaluating Personalized Public Transit Systems.* Federal Transit Administration, Texas Southern University, and Dallas Area Rapid Transit, 1992.

Litman, T. "Measuring Transportation: Traffic, Mobility, and Accessibility." *The ITE Journal,* Vol. 73, No. 10, October 2003, pp. 28–32.

Liu, R., R. Pendyala, and S. Polzin. "A Simulation of the Effects of Intermodal Transfer Penalties on Transit Use." Transportation Research Record 1623, TRB, National Research Council, Washington, D.C., 1998, pp. 88–95.

National Partnership for Reinventing Government. *Balancing Measures: Best Practices in Performance Management.* August 1999. http://govinfo.library.unt.edu/npr/library/papers/bkgrd/balmeasure.html. Accessed October 2007.

National Performance Review. *Serving the American Public: Best Practices in Performance Measurement.* Benchmarking Study Report. June 1997. http://govinfo.library.unt.edu/npr/library/papers/benchmrk/nprbook.html. Accessed October 2007.

Obeng, K. "Total Productive Measurement in Bus Transit: Comment." *Journal of Transportation Engineering,* Vol. 117, No. 6. American Society of Civil Engineers, 1991.

Phillips, J. K. "An Application of the Balanced Scorecard to Public Transit System Performance Assessment." *Transportation Journal,* Vol. 43, No. 1. American Society of Transportation and Logistics, 2004.

Racca, D. P. "Transportation Network Models to Accurately Estimate Transit Level of Service (Paper 1921)," *Proceedings of the Twenty-Fourth Annual ESRI User Conference,* 2004.

Takyi, I. K. "A Multi-Dimensional Methodology for Evaluating Public Transportation Services." *Transportation Research. Part A: Policy and Practice,* Vol. 27, No. 5. Pergamon Press plc; Elsevier, 1993.

Acronyms and Abbreviations

1kVSM	One Thousand Vehicle Service Miles
AAAE	American Association of Airport Executives
AAPM	Airport Automated People Mover
ACC	Airport Consultants Council
ACI-NA	Airports Council International–North America
APM	Automated People Mover
ASCE	American Society of Civil Engineers
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATS	Automatic Train Supervision
CCCS	Control Center Computer System
CDG	Charles De Gaulle Airport in Paris, France
DBOM	Design Build Operate Maintain
JKH	John K. Howell
IT	Information Technology
M&SF	Maintenance and Storage Facility
MTBF	Mean Time Between Failure
MTBHE	Mean Time Between Hazard Element
MTTR	Mean Time to Restore
M/W/DBE	Minority/Woman/Disadvantaged Business Enterprise
N/A	Not Applicable
NTD	National Transit Database
O&M	Operations and Maintenance
PRT	Personal Rapid Transit
RAM	Reliability, Availability, Maintainability
RCSP	Request for Competitive Sealed Proposals
SI	Safety Incidents
slf	Single Lane Feet
TTR	Total Time to Restore
USC	United States Code

EXHIBIT A

Form A, Form B, and Passenger Satisfaction Survey

FORM A

System and Service Descriptive Characteristics

Month: ______ **Year:** ______

Airport: ______

APM System Name: ______

SYSTEM Descriptive Characteristics

Single Lane Feet of Guideway, Mainline:	
Single Lane Feet of Guideway, Other:	
Routes Operated in Maximum Service:	
Trip Time in Maximum Service, by Route:	
Stations:	
Vehicles in Total Fleet:	

SERVICE Descriptive Characteristics

	Month	Year-To-Date
Passenger Trips:		
Vehicle Service Miles:		
Vehicles Operated in Maximum Service:*		
Vehicles Available for Maximum Service:*		
Headway in Maximum Service:*		

* - For YTD column, provide maximum service YTD value.

FORM B: Page 1 of 2

Airport APM Performance Measures

Month: ______ **Year:** ______

Airport: ______

APM System Name: ______

Airport APM Performance Measure #1 - Service Availability

	Month (% or hh:mm:ss)	Year-To-Date (% or hh:mm:ss)
Service Availability * :		
Service Reliability (MTBF) ** :		
Service Maintainability (MTTR) ** :		
Service Mode Availability *** :		
Fleet Availability *** :		
Station Platform Door Availability *** :		

* - Tier "A", Tier "B", and Tier "C" Approaches ** - Tier "B" Approach Only *** - Tier "C" Approach Only

Airport APM Performance Measure #2 - Safety Incidents per 1,000 Vehicle Service Miles (VSM)

	Month (report to the thousandths)	Year-To-Date (report to the thousandths)
Safety Incidents per 1,000 VSM:		

Airport APM Performance Measure #3 - O&M Expense per Vehicle Service Mile (VSM)

	Month (USD)		Year-To-Date (USD)	
	w/Utilities Expense	w/o Utilities Expense	w/Utilities Expense	w/o Utilities Expense
O&M Expense per VSM:				

FORM B: Page 2 of 2

Airport APM Performance Measures

Month: ______ **Year:** ______

Airport: ______

APM System Name: ______

Airport APM Performance Measure #4 - Actual and Scheduled Capacity (Peak vs. All Other)

	Month (cumulative total number of passengers)		Year-To-Date (cumulative total number of passengers)	
	Peak Periods	All Other Periods	Peak Periods	All Other Periods
Scheduled Capacity:				
Actual Capacity:				

Airport APM Performance Measure #5 - Passenger Satisfaction

	Month (report to the hundredths)	Year-To-Date (report to the hundredths)
Passenger Satisfaction:		

Airport APM Performance Measure #6 - Missed Stations per 1,000 Station Stops

	Month (report to the thousandths)	Year-To-Date (report to the thousandths)
Missed Stations per 1K Station Stops:		

Airport APM Performance Measure #7 - Unintended Stops per 1,000 Interstations

	Month (report to the thousandths)	Year-To-Date (report to the thousandths)
Unintended Stops per 1K Interstations:		

PASSENGER SATISFACTION SURVEY

Surveyor (for office use only): ______________________

Date: ______________________

Passenger Name (Optional): ______________________

Passenger Contact Info (Optional): ______________________

____

____

____

A. Please rate your satisfaction with the Automated People Mover (APM) system (circle one):

	Level of Satisfaction					
	Low		Avg.		High	Do Not Know
1. System Availability / Wait Time:	1	2	3	4	5	0
2. Convenience / Trip Time:	1	2	3	4	5	0
3. Comfort / Ride Quality & Cleanliness:	1	2	3	4	5	0
4. Ease of Use / Wayfinding:	1	2	3	4	5	0
5. Informational / Announcements:	1	2	3	4	5	0
6. Helpfulness of Staff:	1	2	3	4	5	0
7. Responsiveness to Complaints:	1	2	3	4	5	0

B. We value your comments. Please let us know how we can better serve you.

____

____

____

____

____

____

Please return this survey to the drop boxes located near the platform exit locations, to any APM system representative, or mail to the address on the reverse side of this card.

APPENDIX A

Contents

SECTION 1

Preface

The objective of ACRP Project 03-07 was to provide a user-friendly guidebook for measuring performance of APM systems at airports. Specifically, the guidebook identifies a set of performance measures and associated data requirements for airport APM operators to assess and improve performance, compare APM systems, and plan and design future APM systems. The performance measures address the efficiency, effectiveness, and quality of APM systems at airports, particularly focusing on impacts on APM passengers and on airport performance.

Throughout the course of the project, research was conducted and work developed that contributed in shaping the guidebook. This research and work, however, are not directly germane to the objective of the guidebook and therefore not appropriate to be incorporated within the main body of that document. As a result, this appendix is provided to document the relevant historical work accomplished on the project that helps form the basis of the main body of the guidebook, including a more detailed summary of the research conducted on performance measurement, generally and as applied to APMs, public transit, airlines, and highways. The appendix also contains information about the survey conducted on the project, including the survey plan specifics, a copy of the survey, and the survey response data and analysis undertaken as part of the research effort.

By providing some of the underlying details of the project's research and work efforts in the appendix, the end user can gain a more thorough understanding of the resulting guidebook and approach provided.

SECTION 2

Research for Performance Measurement

2.1 Research for Performance Measurement—In General

Performance measurement is a type of assessment. It is the ongoing monitoring and reporting of system or program accomplishments, particularly of progress toward preestablished goals [2.1.5—Numbers in brackets throughout this appendix refer to numbered items in the appendix's bibliography.]

A key aspect of a successful performance measurement system is that it makes up a balanced set of a few vital measures. Performance measures may address the type or level of program or system activities conducted (process), the direct products and services delivered by a program or system (outputs), or the results of those products and services (outcomes) [2.1.5]. In any case, measures should:

- Be meaningful;
- Describe how well the goals and objectives are being met;
- Be simple, understandable, logical, and repeatable;
- Show a trend;
- Be unambiguously defined;
- Allow for economical data collection; and
- Be timely and sensitive [2.1.12].

There is an extensive body of research on performance measurement in general, and in particular as applied to public transit, which is described later. For example, the scope of transit performances measures has expanded from simple or limited indicators such as cost [2.1.8] to comprehensive indices such as regularity index [2.1.6] or total productivity index [2.1.13].

There is also a wide range of performance measurement methodologies, including:

- Balanced Scorecard [2.1.7],
- Data envelopment analysis (DEA) [2.1.2],
- Multi-criteria multimodal network analyses [2.1.16],
- Traffic-based,
- Mobility-based, and
- Accessibility-based.

Litman [2.1.9] has suggested that the accessibility-based approach is the best since accessibility is the ultimate goal of most transportation.

It is not possible to describe all performance measures, approaches, or methodologies here since the length of this appendix and scope of the project is limited; however, a few methodologies are briefly documented for potential reference when developing performance measures for APM systems at airports.

2.1.1 Balanced Scoreboard

The Balanced Scorecard approach is a strategic management approach introduced in 1992 by Robert S. Kaplan and David P. Norton of the Harvard Business School [2.1.7]. This management approach galvanized and revolutionized the field. It not only enables organizations to clarify their vision and strategy and translate them into action, but it also provides feedback about both the internal business processes and external outcomes in order to continuously improve strategic performance and results. The Balanced Scorecard approach gained wide use and acclaim in the private sector as a way to build customer and employee data to measure and ensure better performance outcomes. It thus transformed the way private-sector companies could achieve and analyze high levels of performance and was critical in revitalizing such companies as Federal Express, Corning, and Sears [2.1.11].

The Balanced Scorecard approach found its way to the public sector in the later 1990s. Phillips [2.1.14] suggested the application of the Balanced Scorecard to transit performance measures by developing a comprehensive list of constructs and measures for public transit performance assessment (i.e., a shopping list of measures for managers to choose from in constructing their own scorecard). The original four metrics used by this approach for for-profit assessments (financial, internal business, customer, and innovation and learning) were adjusted to fit the unique requirements of a nonprofit, public service. The Balanced Scorecard approach for public use would consider three perspectives: efficiency, effectiveness, and impact. Phillips then details the elements that go into each of the three perspectives and creates constructs for each.

2.1.2 Data Envelopment Analysis

Data envelopment analysis, first put forward by Charnes, Cooper, and Rhodes in 1978 [2.1.2], is a methodology widely used for measuring the relative efficiency of decision-making units, which can be business units, government agencies, police departments, hospitals, educational institutions, and even people. The underlining assumption is fairly simple even though the mathematics can get complex. DEA is a multi-criteria approach, capable of handling multiple inputs and outputs that are expressed in different measurement units. This type of analysis cannot be done with classical statistical methods. Furthermore, because DEA is not a statistical method, one is not constrained by the type and the relations of the data used, as in regression techniques. Inputs and outputs can be anything, including qualitative measurements.

Chu and Fielding [2.1.3] applied the DEA technique in transit performance measurement by developing DEA models for relative efficiency and effectiveness. DEA can measure effectiveness by using consumed service as the output and produced services along with selected external environmental variables as inputs. Chang et al. [2.1.1] extended the model for measuring the relative effectiveness and changes in effectiveness of an organization by merging it with the Malmquist Productivity Approach. The DEA technique may be applied to APM performance measures since APM systems have similar input and output variables, even though the quantity and configurations may be very different.

2.1.3 Network Models

Transportation network models were originally developed to forecast travel demand and simulate traffic conditions. However, model outputs can often be used as comprehensive performance measures for the entire network, individual mode, selected areas, or corridors. The flexibility afforded by transit network analysis often provides the most powerful indicators for measuring the efficiency and effectiveness of transportation networks. Such comprehensive evaluation is extremely important since performance measures of a single mode or isolated sections may distort the results. As demonstrated in an early study of the Hudson–Bergen Light Rail corridor [2.1.10], the level of service can be very different when transfer penalties are included in the analysis, which can only be accomplished via analysis of network models.

In models for public transit usage, the factor representing transit service most often involves the proximity to transit stops, either using walking distance buffers around transit routes or more detailed land use information. These approaches are insufficient to examine the effect transit service has on a person's travel mode decision. In work for the Delaware Transportation Institute [2.1.15], factors for transit level of service were developed using ArcInfo network models that more realistically estimate level of service between specified origins and destinations taking into account walking distances, transfers, wait times, and park and rides. Methods discussed for travel time and distance estimates are applicable for other travel modes as well.

2.1.4 Summary

In short, performance measurement focuses on whether a system or program has achieved its objectives, expressed as measurable performance standards. Because of its ongoing nature, it can serve as an early warning system to management, as a vehicle for improving accountability to the public [2.1.5], as a method to document accomplishments, and as a way to compare similar programs and systems.

2.2 APM Performance Measurement

This study has determined from research of numerous industry documents that current performance measurement of both airport and non-airport APMs is primarily focused on traditional measures of operating system performance (i.e., reliability, maintainability, and availability). Other APM performance measures related to economic efficiency, comfort, and convenience, among others, have received significantly less attention in the literature, if any at all. Some of these measures are applied in other industries, however, and are considered in this appendix for their application to an airport APM. As the research progresses, we anticipate that site visits and surveys will yield more information about these measures from APM system owners and operators.

The documented methods of system performance measurement for airport APMs can be broadly divided into two classes: applied methods and theoretical methods. These classifications are described in the following sub-sections.

2.2.1 Applied Methods

In general, there are four applied methods used in airport APM performance measurement: the System Dependability

Table A-1. APM performance measurement, applied methods.

Method/Measures	No. of Measures	Grace Period	Partial Service Credit	Capacity Considered
System Dependability Method				
Reliability	3	yes	optional	no
Maintainability				
Availability				
Contract Service Dependability Method				
Contract service reliability	3	3 min	no*	no*
Contract service maintainability				
Contract service availability				
System Service Availability Method				
Service mode reliability	6	1 head-way	yes	yes
Service mode maintainability				
Service mode availability				
Fleet availability				
Station platform door availability				
System service availability				
Paris Airport Authority Method				
Contract service availability	1	no	yes	yes**

*In most cases of the literature reviewed
**During degraded mode operations

Method, the Contract Service Dependability Method, the System Service Availability Method, and the Paris Airport Authority Method. These methods are primarily distinguished from one another by the number of factors measured, grace period durations, whether credit is allowed for partial service operations during failures, and whether capacity is a consideration in any of the measures. The methods and characteristics of each are summarized in Table A-1.

Each of the applied methods is described in detail in the following.

2.2.1.1 System Dependability Method

The classical measurement of performance for systems in general, as well as in the APM industry, is the System Dependability Method, as presented in ASCE 21-05, American Society of Civil Engineers, Automated People Mover Standards – Part 1, Chapter 4 [2.2.1]. This method incorporates three measures of overall system performance: reliability, or mean time between failure; maintainability, or mean time to restore; and availability (the ratio of MTBF to the sum of MTBF and MTTR). This method allows for the consideration of grace periods for downtime incurred as a result of an incident or failure, and it also allows for downtime credit during partial service operations. Capacity is not considered as part of this method.

2.2.1.2 Contract Service Dependability Method

The Contract Service Dependability Method was developed by U.S. consulting firm JKH Mobility and has been implemented at some APM systems. The method is very similar to the System Dependability Method in that it incorporates the same three performance measures: reliability, maintainability, and availability. While the older literature revealed that this method previously relied on three sets of the RAM measures (one set called "absolute" RAM, one called "design/operational" RAM, and another called "contract service" RAM), it has today generally evolved into two measure sets—one RAM set where all failures are taken into account and another RAM set where failures that are considered exceptions are not taken into account. This method generally allows for a grace period of 3 min or less for downtime resulting from incidents/failures.

Concerning the method's treatment of partial service credit and capacity considerations, most of the examples of this method revealed that these are not incorporated as part of the method. There were two exceptions, however. The first exception is the method as applied to the pinched loop APM system at Chicago's O'Hare International Airport. There, the system has the capability to operate around many types of failures because its numerous switches and routing combinations, as well as its bidirectional capability, provide a high degree of flexibility. As such, partial service credit is allowed, and system capacity is considered only so far as to make the calculation of the credit [2.2.3 and 2.3.4]. The formula is complicated by the fact that the Chicago system can operate with various train lengths, which forces the consideration of both transportation capacity and headway as well as a corresponding set of specific rules. This is not so in the case of the Paris Airport Authority Method that will be discussed later.

The second exception is the method as applied to the shuttle APM at Orlando International Airport [2.2.10]. Although capacity is normally not considered in this exception at all, a type of partial service credit is allowed in one specific case—during a failure of the scheduled single train operation when the standby train is undergoing maintenance and is unavailable.

2.2.1.3 System Service Availability Method

The System Service Availability Method has been advocated and used by U.S. consulting firm Lea+Elliott since 1994. As a result, it is in wide usage at airport APMs worldwide. The method is distinguished from the other methods by measures that record the performance of subsystems that are most likely to affect passengers. Because the other methods concentrate only on performance as affected by interruptions to system service (i.e., train stoppages), other failures that affect passenger service without interrupting system service are not captured. For example, station platform door failures that deny passengers access to the vehicles affect passenger service and may not be reflected in the measures of the other methods. This method incorporates measures of service mode availability, fleet availability, station platform door availability, and system service availability. The additional availability measures related to fleet and station platform doors ensure that all failures affecting passengers (not just those that interrupt service) are reflected in the overall service availability measure.

The System Service Availability Method also tracks the number of service mode failures, or downtime events, which allows measures of service mode reliability and maintainability to be easily made. These two measures, along with the four availability measures described previously, make up the six measures unique to this method.

The method allows an equivalent of one headway duration or less for a grace period for both incidents/failures and schedule transitions. It also allows for the consideration of downtime credit for partial service operations provided during failures, and it considers capacity as part of its normal measure set rather than during partial service credit only.

The System Service Availability Method, as excerpted in the following, discusses the four measures of availability. Measures of service mode reliability and maintainability previously discussed in this subsection are not presented in the excerpt for the sake of brevity [2.2.6].

System Service Availability Method Described

Service Mode Availability

For each time period and service mode of operation, Service Mode Availability is measured as:

$$A(m) = \frac{\text{Scheduled Mode Operating Hours} - \text{Mode Downtime Hours}}{\text{Scheduled Mode Operating Hours}}$$

where each of the above terms has a precise technical definition, and is subject to recordation of actual conditions.

A Mode Downtime Event is an event in which one or more Operating System-related problems cause an interruption of the normal service provided by the desired operating mode. When such an interruption occurs, downtime for the event shall include all the time from the beginning of the interruption until all trains stopped on the guideway are restarted and normal operation in the scheduled mode is restored (i.e., continuously and normally equal train spacing). Downtime events of a duration that are less than one operational headway shall not be counted in the calculation of service mode availability, but shall be counted for downtime limits purposes. A train stopping on the guideway or failing to depart from a station shall be considered a mode downtime event. Stoppages resulting from causes listed in the following as exclusions shall not be counted as mode downtime events.

Exclusions. The following events are not attributable to the Operating System itself and are not mode downtime events. Delays due to these exclusions are not to be used in determining service mode availability, and shall result in the entire period affected by them being deleted from consideration in calculating service mode availability (i.e., Scheduled Mode Operating Hours is reduced), but not from data collection and storage. All data collection means shall include all periods of time.

1. The time period to transition from one scheduled operating mode to another scheduled operating mode or adjusting scheduled fleet size. Valid transition periods shall not be counted in calculating A_m. Time in excess of allowable transition time by more than one operational headway, as operated during the peak period for the route, shall not be excluded, but the availability achieved during that period shall be adjusted by a "K" factor. The time to change into and out of a lesser, nonscheduled, operating mode due to a failure of the scheduled, or higher-order backup, operating mode shall not be excluded, but shall be counted as the lower of the operating modes.
2. Passenger-induced interruptions or delays.
3. Interruptions caused by intrusions of unauthorized persons or of animate or inanimate objects into non-public areas of the Operating System.
4. Interruptions caused by non-Operating System induced loss of service, e.g., loss of utility service, electrical power provided outside the nominal range, vehicle diversion resulting from intended security responses, force majeure, and acts or omissions of the Owner or its agents or contractors.
5. Periods of scheduled operating times when the specified environmental limits are exceeded.
6. Periods when the Fixed Facilities are not available, unless their unavailability is attributable to the Contractor or its vehicles/subsystems.
7. Operational delays induced by the ATC system to regulate train operations, maintain schedules and for anti-bunching; where such delays do not exceed the operational headway for the route.

K-Factor. Used to calculate partial Operating System mode availability during failure mode operations. When the Operating System is not in any failure mode, K factor shall be equal to one. If a downtime event occurs and service is not restored within the time specified to that scheduled for the Operating System, but rather a lesser service mode is operated for failure management, then the entire time period for operating in any failure mode shall be counted as partial mode downtime. To determine A(m), for the time period the Operating System operates in failure mode, the appropriate K factor shall be used.

Fleet Availability

For each time period and service mode of operation, Fleet Availability is measured as:

$$A(f) = \frac{\text{Actual Car Hours}}{\text{Scheduled Car Hours}}$$

where each of the above terms has a precise technical definition and is subject to recordation of actual conditions.

Station Platform Door Availability

For each time period and service mode of operation, Station Platform Door Availability is measured as:

$$A(s) = \frac{\text{Actual Platform Door Hours}}{\text{Scheduled Platform Door Hours}}$$

where each of the above terms has a precise technical definition and is subject to recordation of actual conditions.

System Service Availability

For each time period (I), System Service Availability is measured as:

$$A(I) = Am(I) \times Af(I) \times As(I)$$

where Am(I), Af(I) and As(I) are measured as described above.

2.2.1.4 Paris Airport Authority Method

The Paris Airport Authority (Aeroports de Paris) Method is a variation on the System Dependability Method (ASCE) discussed previously. It was introduced by Aeroports de Paris and ALONEX for Line 1 of the APM system at Roissy Charles-de-Gaulle Airport [2.2.8]. Unlike the other methods, it calculates contracted service availability on the basis of service unavailability, and in so doing, eliminates from the calculation any need to consider grace periods or the downtime exclusions common to the other methods. (The other methods are similar in that they exclude the consideration of downtime caused by external sources, such as passenger-induced delays, interruptions caused by intrusions of unauthorized persons or objects, and other external sources beyond the control of the system or operating entity.)

Working from the perspective of service unavailability, the goal of this method is to take into account the transportation capacity of the system during periods of degraded mode operations. Providing the ability to earn this partial service credit, and tying the contracted service availability to payment, is an incentive to the operator to provide the best possible transportation capacity during failures. Although the path to calculating the contracted service availability number is different, the partial service credit incentive concept is very similar to the approach used for the Chicago O'Hare APM discussed previously. One significant difference is that whereas the Chicago APM must deal with a specific approach due to its variable length trains, the CDG APM system does not (it has fixed-length trains). Both of these APM systems, Roissy Charles-de-Gaulle and Chicago O'Hare, are supplied by the same APM system manufacturer, Siemens, which may explain why the methods are similar, at least in the context of partial service allowances.

2.2.2 Theoretical Methods

The literature review and analysis have also revealed that APM performance measurement has been studied and reported on theoretically. Three papers in particular have been presented in this area.

2.2.2.1 Airport APM Performance Measurement: Network Configuration and Service Availability

The first paper, "Airport APM Performance Measurement: Network Configuration and Service Availability," was presented in 2007 at the 11th International ASCE APM Conference in Vienna [2.2.5]. It was written by Wayne D. Cottrell, Associate Professor at California State Polytechnic University, and Yuko J. Nakanishi, President of Nakanishi Research and Consulting, LLC.

The paper examines service availability and reliability and how they are affected by airport automated people mover network configurations and other system parameters. The paper affirms the importance of availability and reliability measurements in the APM industry that was discussed previously in Section 2.2.1: Applied Methods.

The paper suggests that detailed measures of headway regularity would be useful in an empirical study of AAPM reliability performance. Measures that are set forth include headway adherence, service regularity, headway ratio, headway regularity index, and headway deviation.

The ultimate conclusion is that network configuration affects the reliability and availability of airport APMs, albeit in a limited way due to the limited variety of airport APM networks. Other system parameters such as consist size and the number of in-service trains also affect reliability and availability.

2.2.2.2 Defining and Measuring Service Availability for Complex Transportation Networks

The second paper, "Defining and Measuring Service Availability for Complex Transportation Networks," was presented in 1996 at the International Conference on Personal Rapid Transit (PRT) and Other Emerging Transportation Systems in Minneapolis [2.2.7]. It was written by Charles P. Elms, a former Principal of U.S. consulting firm Lea+Elliott, Inc.

The paper first defines measures of service availability in current use and analyzes exact and approximation methods for data collection and computation. It then postulates and explores classical and new definitions of service availability applicable for complex networks such as PRT. Insight is provided for choosing a suitable definition based on the type of transportation network.

The methodology in the paper is based on the classical approach of service mode availability [MTBF/(MTBF + MTTR)], and adjusts for fleet availability and station platform door availability. Ultimately, the methodology outlined in the paper aligns with the System Service Availability Method discussed previously.

2.2.2.3 RAM: Reliability, Availability and Maintainability of APM Systems

The third paper, "RAM: Reliability, Availability and Maintainability of Automated People Movers," was presented in 1989 by John K. Howell of U.S. consulting firm JKH Mobility at the Second International Conference on APMs in Miami [2.2.11].

The paper discusses in detail reliability theory in particular, as well as the factors that influence reliability (MTBF), maintainability (MTTR), and availability in an APM system. It also describes approaches to specifying contract service requirements based on classical definitions of MTBF, MTTR, and availability. The paper ends with a discussion of RAM monitoring and accountability.

The methodology in the paper is generally based on the classical approach of availability [MTBF/(MTBF + MTTR)] and aligns with the Contract Service Availability Method discussed previously.

2.3 Public Transit Performance Measurement

This section is a summary of the key findings of performance measurement used in the public transit industry. It contains subsections with discussions in three areas: the historical development of public transit measures, providing a brief overview of the history and current practices of performance measurement in the public transit industry; concentrated efforts in the area of public transit performance measurement, focusing on two efforts of performance measurement in the transit industry; and international practices, containing examples of measuring transit performance in the international arena.

2.3.1 Historical Development

There is a large literature base that exists today about performance measures in the transit industry. However, two or three decades ago, the landscape on transit performance measures was fairly similar to that of airport APM systems today. That is, no systematic approach existed.

Some early documents on transit performance evaluations can be traced back to the early 1980s [2.3.1, 2.3.2, 2.3.6, and 2.3.22]. Based on the fact that most obstacles to the comparative evaluation of transit performance lie chiefly in the nonconformity and inaccuracy of the data and the inadequate coverage of the local operating characteristics, studies around this period tended to address the need for data collection and systematic analysis of the data collected. After May 1981, however, this first obstacle was overcome with the publication of the annual reports required by Section 15 of the Urban Mass Transportation Act of 1964 [2.3.1]. However, the data analysis techniques were limited to rudimentary statistical correlation and regression analysis [2.3.2], and performance measures were still in the stages of infancy [2.3.6]. This Section 15 reporting by U.S. transit agencies continues but is known today as the National Transit Database [2.3.12]. The NTD program is discussed in more detail later in this section.

Another trend in the early development of transit performance measures was the mode-specific approach, which is still practiced today and may have potential to be applied to airport APM systems. Topp [2.3.18] conducted an extensive study of Toronto Light Rail services to identify potential problems, practical performance measures, and policies linked with performance evaluations. Rouphail [2.3.15] examined performance evaluation of bus priority measured in the Chicago Loop. And Lauritzen [2.3.8] examined the first year operation of the Chicago Transit Authority's special services, using performance measures tailored to those services.

An early framework for transit performance concepts was presented by Fielding [2.3.3], where cost efficiency, service effectiveness, and cost effectiveness were the terms used to describe the three dimensions of transit performance. Other studies [2.3.4 and 3.3.5] applied this framework for performance evaluation.

Lew, Li, and Wachs [2.3.9] carried the framework of transit performance measures one step further by defining several categories of common indicators. They identified three critical limitations to commonly used performance indicators and proposed a new set of intermodal performance indicators. The new proposed indicators overcame the limitations of single-mode indicators by incorporating mechanisms for comparison of one mode to another, for rating the performance of systems that include multiple modes, and by incorporating both capital and operating costs.

Advancement in systematic transit performance measures was documented in a study by Kopp, Moriarty, and Pitstick [2.3.7]. Past transit performance measures typically focused on attributes of service supply such as capacity, passenger loading, frequency, and reliability. These measures were effective in describing the quality of transit service available at a given location, but they did not describe how well transit serves actual passenger trips from that location to potential destinations. Kopp and his coauthors developed a methodology to evaluate the relative attractiveness of travel by public transit and personal automobile on a sample of origin–destination pairs throughout the Chicago metropolitan region. Transit attractiveness was computed by using a logit mode choice framework that compared the utility of travel by transit, auto, and park-and-ride for various components of travel time and travel cost.

2.3.2 Concentrated Efforts

Many more performance measures have been developed and used in a variety of ways in response to differing transit system goals and objectives. What is currently missing is a rigorous process for determining the most appropriate performance measures to be used by a transit organization. Furthermore, traditional service efficiency indicators, such as operating expense per vehicle revenue mile and/or hour, and cost-effectiveness indicators, such as operating expense per passenger mile and/or passenger trip, are not always linked to customer-oriented and community issues.

There have been two major efforts in recent years to develop a process that transit systems can use to prepare a performance-measurement program sensitive to customer-oriented and community issues and showcase the potential examples and lessons learned. The first concentrated effort was TCRP Project G-06, the results of which were documented in *TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System* [2.3.19]. The second effort was a series of conferences on performance measures to improve transportation systems and agency operations held in Irvine, California, in 2000 and 2004 [2.3.20 and 2.3.21]. Even though there are a number of studies and conferences related to the subject of transit performance measures, we have highlighted the content of these two efforts in an effort to narrow the focus of the topic.

2.3.2.1 TCRP Report 88

The objectives of this TCRP research were to provide a framework by which to select and apply appropriate performance measures integral to transit-system decision making. The study explored various subjects directly related to transit performance measures, such as purpose, characteristics, and uses of various indicators. The study also focused on a number of case studies of various transit systems to gather effective performance measures.

As a result of the study *TCRP Report 88: A Guidebook for Developing a Transit Performance-Measurement System* was produced [2.3.19]. This guidebook assists transit system managers in developing a performance-measurement system or program that uses traditional and nontraditional performance measures to address customer and community issues.

The guidebook contains six chapters, each covering a different aspect of developing a performance-measurement program:

- Chapter 1 describes how to use the guidebook.
- Chapter 2 makes the case for why agencies should measure their performance.
- Chapter 3 presents 12 case studies of successful programs.
- Chapter 4 provides an eight-step process for implementing, using, and periodically updating a program.
- Chapter 5 describes resources available to agencies developing or updating a program.
- Chapter 6 contains 130 summaries describing more than 400 individual performance measures and a series of selection menus to help users quickly identify measures appropriate to particular agency goals and resources.

In addition to the report, a computer program was developed for the purpose of gathering transit performance measures. Using Florida Transit evaluation data as the foundation, the program can be used to process National Transit Database (also known as Section 15) data. The software is useful to compare transit performances of various peer agencies.

As one of the concentrated efforts in developing transit performance measures, the TCRP report compiled a fairly comprehensive database and explored an effective process. The process is useful for the development of airport APM performance measures even though the indicators may be different.

2.3.2.2 Conferences on Transportation Performance Measures

There have been two conferences on performance measures held in the past several years, the topics of which go back to the growing interest and debates that surrounded the development and use of performance measures to guide investment decisions at all levels of government.

The first national conference on performance measures, held in Irvine, California, in 2000 [2.3.20], brought together a group of government, academic, and business leaders who had experience in transportation system performance measures and performance-based planning and programming. The conference included transit but was not limited to it. The conference's purpose was to address organizational approaches, implementation experiences, customer perspectives, and technical issues related to performance measures of transportation systems.

Covering performance measures of multimodal transportation systems, the conference was organized around four main topics:

1. Linking performance measures with decision making;
2. Implementing transportation system performance measures in agencies;
3. Selecting measures, data needs, and analytical issues; and
4. Connecting system performance measures to broader goals.

The second national performance measure conference, held in Irvine, California, in 2004 [2.3.21], served as a milestone to define the state of the practice and acknowledge recent work in the use of performance measures, share experiences and resources, and identify key areas that needed further research or additional peer exchange.

Designed to maximize the exchange of information and perspectives among the participants, the second conference on performance measures commissioned a series of resource papers on the five themes discussed during the conference:

1. Performance measures—state of the practice;
2. Impact of performance measures on internal and external relationships;
3. Tying together performance-based program development and delivery;
4. Data and tools required to support decision making; and
5. Measuring performance in difficult-to-measure areas.

Individual papers or presentations from these conferences may be applicable to the development of performance measures for airport APM systems.

2.3.2.3 National Transit Database

The National Transit Database is the FTA's primary national database for statistics on the transit industry. Recipients of FTA Urbanized Area Formula Program grants (§5307) and Nonurbanized Area Formula Program grants (§5311) are required by statute to submit data to the NTD. Over 650 transit agencies and authorities file annual reports to FTA through the internet-based reporting system. Each year, NTD performance data are used to apportion over $4 billion of FTA funds to transit agencies in urbanized areas. Annual NTD reports are submitted to Congress summarizing transit service and safety data [2.3.12].

The NTD is the system through which FTA collects uniform data needed by the Secretary of Transportation to administer department programs. The data consist of selected financial and operating data that describe public transportation characteristics for all types of transit modes, including but not limited to bus, heavy rail, light rail, monorail, automated guideway transit (AGT), ferry, inclined plane, and vanpool. These data include performance measures in the areas of service efficiency, cost effectiveness, and service effectiveness. Specifically, they include the following measures:

- Service efficiency
  - Operating expenses per vehicle revenue mile
  - Operating expenses per vehicle revenue hour
- Cost effectiveness
  - Operating expenses per passenger mile
  - Operating expenses per unlinked passenger trip
- Service effectiveness
  - Unlinked passenger trips per vehicle revenue mile
  - Unlinked passenger trips per vehicle revenue hour [2.3.12]

These measures may be applicable to airport APM systems and merit further analysis. For those measures involving a cost/expense component, the type of expense information applied in the measure would have to be studied carefully to ensure the same or similar information would be included. The measures containing a vehicle-hour component, however, may not be appropriately applied to the APM industry in general since vehicle hours are closely tied in traditional public transit to vehicle operator expenses and time, which, because of the fully automated nature of the systems, do not exist in the APM industry.

A list of safety and security data collected by the NTD program is provided as follows.

- Safety
  - Collisions
  - Derailments
  - Fires
  - Fatalities/injuries
  - Evacuation
  - Suicides (attempting/committing/others affected)
- Security
  - Part I offenses
    - Robbery
    - Aggravated assault
    - Burglary
    - Larceny/theft offenses
    - Motor vehicle theft
    - Arson

- Part II offenses
  - Fare evasion (citations)
  - Other assaults (arrests)
  - Trespassing (arrests)
  - Vandalism (arrests)
- Other security issues
  - Bomb threats
  - Nonviolent civil disturbances [2.3.13]

Some of these safety and security incidents that one would see in an urban transit system, or even in an urban APM system, might be different from what is seen in an airport APM system. Because of this, these data should be studied further to determine their applicability to airport APM systems and how they might best be developed into effective performance measures.

2.3.3 International Practices

In order to identify the use of performance measures in different institutional and cultural contexts, Meyer [2.3.11] examined the use of performance measures in three countries: Australia, Japan, and New Zealand. This work represented an international review on performance measures and was sponsored by the FHWA and AASHTO. After discussing the organizational context for the use of performance measures, identifying key performance measures, and making observations on aspects of the performance-based planning approach used, the author highlighted performance measures related to safety, congestion, and freight movement. The paper noted the following common characteristics of each case:

- The use of a common framework for performance measurement;
- The importance of collaboration among different agencies for performance categories that transcend one policy area;
- The use of performance measures at different levels of planning and decision making;
- The vertical integration of information flow in agencies;
- The distinction between outcomes and outputs, the importance of data-collection capability, and the use of information technologies;
- The importance of performance measurement as a means of providing greater accountability and visibility to the public; and
- The need for top management leadership and commitment.

The Meyer publication brought home performance measurement experience taking place in three different institutional and cultural contexts. The common characteristics of each provide an important understanding of how such measurement can be used in many different settings. It is also interesting to observe what measures and processes were similar to those found in the United States.

Rystam and Renolen [2.3.16] developed a guidebook for evaluating measures in public transit systems based on experiences from the evaluations of several public transit projects in Norway and Sweden. The guidelines may be used by planners, consultants, and municipalities. The guideline is a general document so that it can be used as a basis when evaluating minor as well as major public transit systems.

Another international example of transit performance measures came from Thailand [2.3.17]. This study demonstrated that the performance indicator analysis technique can be used as a diagnostic tool to identify operational inefficiency and ineffectiveness at the route level of transit operation. Applying the technique to 14 bus routes of the Bangkok Mass Transit Authority, the research revealed the inter-route differences in operational efficiency and effectiveness. The authors selected 20 performance indicators related to costs of services, fuel consumption, staff ratio, crew productivity, fleet utilization, service output per bus, daily revenues, and so forth to represent the resource efficiency, resource effectiveness, and service effectiveness of the bus system. Results of the analyses revealed that considerable variations existed across the routes against many of these 20 selected indicators.

Light rail transit (LRT) is the focus of another international application of transit performance measures [2.3.10], which may have direct implications for developing airport APM performance measures due to the common characteristics of the modes. Conducted by the Urban Transport Group of the European Conference of Ministers of Transport, this study was based on case studies and national overviews provided by the six participating countries: France, Germany, the Netherlands, Switzerland, the United Kingdom, and the United States. The research traced the development of LRT; reviewed policy, managerial, and technological trends; and analyzed comparative cost-effectiveness. The standardized framework developed for the project allowed consistent comparisons of the international systems.

2.4 Airline Performance Measurement

This section is a summary of the key findings of performance measurement as it relates to the airline industry. Four airline performance measurement areas are discussed in this section: government-monitored measures, airport operator/airline measures, other airport agency measures, and measures resulting from design recommendations, standards, and levels of service.

Performance measures in the airline industry generally take two forms: financial and nonfinancial. Financial performance measures relate some function of cost to an individual unit such as aircraft or originating passenger. Nonfinancial performance measures usually have no component of cost associated with them. Both types of performance measures could be applied to airport APM systems. In this section, performance measures found in the airline industry will be discussed along with the possible application to airport APM systems.

2.4.1 Government-Monitored Measures

The most widely reported nonfinancial performance measures of airlines are collected by government agencies such as the FAA, the United States Department of Transportation (U.S. DOT), and the National Transportation Safety Board (NTSB). These performance measures are used to assess and compare airline performance across the industry. The performance measures collected by the government agencies include:

1. On-time performance,
2. Oversales,
3. Mishandled baggage,
4. Consumer complaints,
5. Accidents and incidents, and
6. Runway incursions.

These statistics and others are presented in the *Air Travel Consumer Report* [2.4.1], which is presented on the U.S. DOT's website, http://airconsumer.ost.dot.gov/reports/index.htm.

On-time performance measures are collected for both arriving and departing aircraft. When aircraft are not considered on time, the reasons for the delays are recorded. The percent of on-time arrivals by airline is just one of the statistics presented in the *Air Travel Consumer Report.* These statistics can be translated to airport APM systems. However, since APM systems typically operate on a headway basis rather than a schedule basis, a statistic measuring of the frequency of trains may be more useful.

The second measure is the number of oversales, or the number of passengers who hold confirmed reservations and are denied boarding on a flight because it is oversold. These include both voluntary and involuntary denied boardings. The first accounts for those passengers who voluntarily give up their seats in exchange for compensation. The second accounts from those passengers who did not volunteer to give up their seats but were denied boarding (bumped) and who may have received compensation. Similar statistics could be collected for airport APM systems to facilitate the operation of the APM. For example, the number of denied boardings due to trains being at capacity could be collected to determine when additional vehicles need to be put into operation to satisfy increased demand. There are also occasions when passengers voluntarily remain on the platform, such as when they have plenty of time and do not want to squeeze into an occupied vehicle. Both of these types of denied boardings could provide useful information regarding the performance of an airport APM system. However, collecting such data may prove to be difficult.

The third measure on the list is the rate of mishandled passenger baggage. The airlines report the number of incidents for lost, damaged, delayed, or pilfered baggage. The airlines that are required to report these statistics are ranked in the *Air Travel Consumer Report* based on lowest to highest rate of mishandled baggage. This statistic is not directly translatable to airport APM systems because passengers handle their own baggage. While there may be a need in the future to collect such statistics for airport APM systems, the need for mishandled baggage statistics is not expected in the foreseeable future.

The fourth measure on the list concerns consumer complaints. The number and type of complaints filed with the U.S. DOT are collected and reported in a variety of formats. The types of reports filed include flight problems, baggage, customer service, oversales, and disabilities. Similar data could be collected for airport APM systems to determine the types of problems encountered by passengers. These statistics could be used by the system operator to improve the level of service provided to passengers.

The fifth measure on the list is collected by the NTSB and reported to the FAA regarding accidents and incidents. The report lists all accidents and incidents, including those resulting in fatalities, by aircraft type. Summary data are presented in both preliminary and final reports. More detailed accident and incident data are also collected and reported by the NTSB. Accident and incident data could also be collected for airport APM systems to measure the safety of the system operation, both with regard to passengers and vehicles. These data could then be reviewed to determine when problems exist and corrective actions should be taken.

The final measure concerns runway incursions and is collected by the FAA. A runway incursion is "any occurrence in the airport runway environment involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in a loss of required separation with an aircraft taking off, intending to take off, landing, or intending to land" [2.4.6]. A similar measure for incursions on an APM guideway should normally not be necessary given the security and precautions that are taken during design, installation, and operation of an APM system. However, there are instances where incursions, in the form of objects and/or passengers rather than between vehicles, can interfere with APM operations. For example, an open pedestrian bridge crossing above an APM at a particular airport has contributed to objects being dropped on the guideway and causing service interruptions to either retrieve the object or recover from failures induced by the object. Similarly, a voluntary evacuation from a stopped vehicle on the guideway provides access by passengers to the secure (guideway) side of the system, thereby causing a system shutdown. Given the impact that these incursions can have on an airport APM system, up to and including a temporary suspension of service across the entire line, it may be useful to develop performance measures in this area.

2.4.1.1 BTS-Monitored Measures

Financial, employment, and traffic performance measures for airlines are collected and reported by the Bureau of Transportation Statistics (BTS). These performance measures represent standard airline industry units of production, various output measurements, and output valuations. There are four financial measures and seven employment and traffic measures.

Financial Measures. Financial measures collected and reported by the BTS are:

1. System operating profit/loss per originating passenger,
2. System operating expenses per originating passenger,
3. System operating expenses per aircraft, and
4. Passenger revenue per originating passenger [2.4.2].

With regard to the financial measures, since airport APM systems provide nonrevenue service to passengers, data regarding profit, loss, and revenues are not relevant. However, operating expenses are relevant. Statistics regarding operating expenses per passenger or vehicle revenue mile may be useful in evaluating the APM system or making comparisons between different system technologies. Therefore, financial performance measures similar to those used in the airline industry may be relevant to airport APM systems.

Employment and Traffic Measures. Employment and traffic measures collected by the BTS are:

1. Full-time equivalent employees per aircraft,
2. Average monthly available seat-miles per full-time equivalent employee,
3. Average monthly revenue aircraft minutes per full-time equivalent employee,
4. Average monthly originating passengers per full-time equivalent employee,
5. Fuel cost per originating passenger;,
6. Average full-time equivalent employee compensation per originating passenger, and
7. Average annual full-time equivalent employee compensation [2.4.2].

The majority of the employment and traffic measures listed previously relate to employees. Perhaps the most meaningful statistic with regard to airport APM systems is full-time equivalent employees per aircraft. A similar statistic could provide airport APM system operators with a measure of employees per vehicle or employees per vehicle revenue mile that could be useful when comparing systems or when considering expansion plans.

2.4.2 Airport Operator/Airline Measures

The performance measures discussed in the preceding paragraphs are collected and reported by government agencies and not by the airports or airlines. While those performance measures are useful to the airports and airlines, there are additional performance measures that airports and airlines use to gauge and monitor performance. The performance measures discussed in the following can be considered internal measures, used to monitor employee and process performance.

Many airports and airlines have established performance measures for wait time in queue and baggage delivery time to baggage carousel. The following list is an example of the types of processes that are monitored:

- First bag delivery to baggage claim,
- Last bag delivery to baggage claim,
- Curbside check-in time,
- Ticket counter check-in time,
- Security checkpoint wait time,
- Gate check-in time, and
- Personal space allocation in queues and waiting areas.

The standards against which performance is gauged are not universally defined for these measures but instead are set by individual airports or airlines. For example, one airport operator set a standard of a maximum of 15 min after aircraft arrival for the first bag to be delivered to baggage claim, while another airport operator has a maximum of 5 min for international baggage and 10 min for domestic baggage. Similarly, one airport operator has a standard of a maximum of 20 min to reach a counter for ticket counter check-in, while another requires that 95% of passengers be served with 12 min.

While baggage delivery times may not be relevant to airport APM systems, the wait time and personal space allocation measures may be. Airport APM systems should be operated such that passenger demand is satisfied and that adequate personal space is provided. However, as demand grows or as airlines change their schedules, airport APM systems have to adapt to continue to provide passengers with a high level of service. Wait times for trains should be considered so that passengers do not become anxious that they may not make their connecting flights. Similarly, passengers prefer adequate personal space on platforms and trains. Periodic monitoring of the wait times and personal space allocations may be useful to be sure that passengers have a comfortable experience using the APM.

2.4.3 Other Airport Agency Measures

Agencies operating at airports, such as immigration services, have performance criteria they use to determine proper staffing levels and space requirements. International airport organizations also have defined standards for performance to be used in the planning and monitoring of the immigration services function.

The International Air Transport Association (IATA) defines level-of-service space requirements for passport control [2.4.8], while the International Civil Aviation Organization (ICAO) has standards for the processing of passengers from an arriving aircraft [2.4.9]. Immigration agencies have also set standards for how long passengers wait for immigration processing and how much space they should be allocated.

As discussed in the previous section, the wait time and personal space allocation measures are relevant to airport APM systems. Just as the immigration services consider the passenger wait times and space allocation in monitoring performance, airport APM system operators may benefit from applying these same types of performance measures.

2.4.4 Design Recommendations, Standards, and Levels of Service

Finally, there are level-of-service recommendations used by airport developers, planners, and designers that, while not expressly intended as performance measures, can be used to gauge and compare the efficiency and performance of airport facilities. For example, the *Airport Development Reference Manual* published by IATA is frequently used as a guide for those planning new or expanding existing airport facilities. While the manual presents recommendations, they have, in fact, come to be viewed as standards [2.4.8].

Perhaps the most relevant recommendations presented in the manual for airport APM applications are those pertaining to walk distances, wait times, and space occupancy. For example, IATA recommends that the maximum unassisted walking distance between major airport functions be 300 m. In assessing airport APM system designs or comparing one system to another, the maximum walk distance can be used as a measure of the level of passenger service provided.

The waiting time guidelines recommended by IATA for various airport facilities are akin to passenger wait time for an APM train. The idea is to set a maximum wait time as a standard so that passengers do not become uncomfortable and anxious. Maximum wait time as a measure of passenger service for airport APM systems is a reasonable extension of the IATA wait-time guidelines.

Similarly, IATA recommends level-of-service and space standards for many airport facilities, such as check-in and baggage claim areas. Level-of-service standards can be defined for airport APM platforms and vehicles as a means of comparing the level of service provided by different systems or for determining when additional trains are required.

In addition, John J. Fruin's *Pedestrian Planning and Design* [2.4.7] provides recommendations for personal space allocation and has become a handbook for designers and planners. Fruin's level-of-service standards are based on a six-point scale, with "A" being the best level of service and "F" being unacceptable service.

2.5 Highway Performance Measurement

This section is a summary of the key findings of performance measurement as it relates to the highway industry on the national level. Three areas are discussed in this section: performance measurement activities of the FHWA, the National Transportation Operations Coalition, and a review of NCHRP Project 3-68, "Guide to Effective Freeway Performance Measurement" (the final report for which was produced as *NCHRP Web-Only Document 97: Guide to Effective Freeway Performance Measurement*) [2.5.6].

2.5.1 FHWA Performance Measurement Program

The FHWA's Office of Operations supports a performance measurement program focused on system (highway) performance as it relates to mitigation of congestion. The program measures the sources and consequences of congestion, and the effectiveness of operations strategies to reduce that congestion [2.5.5].

Some examples of congestion performance measures that can be used by highway agencies to monitor trends are provided in Table A-2.

While many of these metrics may be useful in the highway industry, one of the principles that the FHWA has established for monitoring congestion is that meaningful congestion performance measures must be based on the measurement of travel time. The reason for this is that travel time is easily understood by a wide variety of audiences—both technical and nontechnical—and it can be used from both a user and owner/agency perspective. In particular, the FHWA has identified travel time reliability and its associated measures as the most effective measures of (highway) system performance from the user's perspective [2.5.5]. As a result, this

Table A-2. Examples of congestion performance measures used by highway agencies.

Performance Metric	Definition/Comments
Throughput	
Vehicle miles of travel (VMT)	Vehicle miles of travel is the number of vehicles on the system times the length of highway they travel. Person miles of travel is used to adjust for the fact that some vehicles carry more than a driver.
Truck-vehicle miles of travel	
Person miles of travel	
Average Congestion Conditions	
Average travel speed	The average speed of vehicles measured between two points.
Travel time	The time it takes for vehicles to travel between two points. Both travel time and average travel speed are good measures for specific trips or within a corridor.
Number and percent of trips with travel times > (1.5 × average travel time)	Thresholds of 1.5 and 2.0 times the average may be adjusted to local conditions; additional thresholds may also be defined.
Number and percent of trips with travel times > (2.0 × average travel time)	
Travel time index	Ratio of actual travel time to an ideal (free-flow) travel time. Free-flow conditions on freeways are travel times at a speed of 60 mph.
Total delay (vehicle hours and person hours)	Delay is the number of hours spent in traffic beyond what would normally occur if travel could be done at the ideal speed. Determining delay by source of congestion requires detailed information on the nature and extent of events (incidents, weather, and work zones) as well as measured travel conditions.
Bottleneck (recurring) delay (vehicle hours)	
Traffic incident delay (vehicle hours)	
Work zone delay (vehicle hours)	
Weather delay (vehicle hours)	
Ramp delay (vehicle hours and person hours; where ramp metering exists)	
Delay per person	Delay per person and delay per vehicle require knowledge of how many vehicles and persons are using the roadway.
Delay per vehicle	
Percent of VMT with average speeds <45 mph	
Percent of VMT with average speeds <30 mph	
Percent of day with average speeds <45 mph	These measures capture the duration of congestion.
Percent of day with average speeds <30 mph	
Reliability	
Planning time (computed for actual travel time and the travel time index)	The 95th percentile of a distribution is the number above which only 5% of the total distribution remains. That is, only 5% of the observations exceed the 95th percentile. For commuters, this means that for 19 out of 20 workdays in a month, their trips will take no more than the planning time.
Planning time index (computed for actual travel time and the travel time index)	Ratio of the 95th percentile (planning time) to the ideal or free-flow travel time (the travel time that occurs when very light traffic is present—about 60 mph on most freeways).
Buffer index	Represents the extra time (buffer) most travelers add to their average travel time when planning trips.
For a specific road section and time period: Buffer index (%) =	$\frac{\text{95th percentile travel time} - \text{average travel time}}{\text{average travel time}}$

Source: [2.5.1]

section will focus on travel time reliability and the measures that quantify it.

Travel time reliability is the consistency or dependability in travel times, as measured from day to day and/or across different times of the day. It better represents a commuter's experience than a simple average travel time measurement. It is important because most travelers are less tolerant of unexpected delays (nonrecurring congestion) than of everyday congestion, and they also tend to remember bad traffic days over an average daily travel time throughout the year. The recommended measures used to quantify travel time reliability are 90th or 95th percentile travel time, buffer index, and planning time index [2.5.4].

2.5.1.1 90th or 95th Percentile Travel Time

The 90th or 95th percentile travel time measure is simply an estimate in minutes of how bad delays will be on certain routes during the heaviest traffic days. The 90th or 95th percentile represents those days in the month that are the heaviest traffic days causing the greatest congestion and longest travel times; it is the near-worst-case travel time. This method requires continuous tracking of travel times in order to provide an accurate estimate. State departments of transportation employ this method for use by the public online. A traveler can, for example, determine on a website that the 95% reliable travel time for a particular route is 59 min, which means that if the traveler allows 59 min for the trip on that route, he or she would be on time 19 out of 20 weekdays in the month [2.5.4].

This measure is ideally suited for traveler information in that it provides a gauge of how many times in a month, for example, the travel time can be relied upon. It does not obviously predict the day(s) when the 90th or 95th travel time may occur, but used in conjunction with other measures to be described in the following subsections, a reasonable probability of arriving on time can be computed. From the agency's view, this measure may be useful in that it can track the creep in the average travel time over a period of time (i.e., the 59-min travel time may creep to 63 min over time). This would be useful in planning for the mitigation of congestion, whether in the form of providing additional infrastructure or employing other techniques such as HOV lanes, directional lanes by time of day, or other operational strategies.

As applied to the airport APM industry, providing this measure to the traveling public may not be as useful as in the highway industry since APM travel times tend to be relatively short, thereby making the measure less meaningful. In addition, the high availability of airport APM systems (99%+) provides more dependable transportation than a highway system, where there is a great variation from average or typical conditions. By its very nature, roadway performance is highly variable and unpredictable, in that on any given day, unusual circumstances such as vehicle accidents can dramatically change the performance of the roadway, affecting both travel speeds and throughput volumes. Because travel conditions are so unreliable on congested highways, travelers must plan for these problems by leaving early to avoid being late [2.5.1].

In terms of an agency/operator using this as an internal measure for an APM system, it may not be meaningful because airport APM systems tend to have a high level of availability and do not have wide variances in the travel times found on the roadways (i.e., whereas the 90th or 95th percentile travel times for a highway will provide a measurable level of travel time and unavailability over a month's time, an airport APM system may not).

2.5.1.2 Buffer and Planning Time Indices

Another effective travel time reliability measure in the highway industry is the buffer index. The buffer index, presented as a percentage, represents the extra time travelers must add to their average travel time when planning trips in order to ensure an on-time arrival most of the time. It is expressed as a percentage, and its value increases as reliability gets worse. For example, if the average travel time is 30 min and the buffer index is 40%, a traveler should allow an additional 12 min to rely on an on-time arrival 95% of the time. The extra 12 min is called the buffer time. The buffer index is computed as the difference between the 95th percentile travel time and the average travel time, divided by the average travel time.

The planning time index measure represents the total travel time that should be planned for a trip and includes an adequate buffer time to rely on an on-time arrival of 95%. For the previous example, the planning index would be 1.40. The planning time index differs from the buffer index in that it includes typical delay as well as unexpected delay. In addition, where the buffer index is used in determining the additional time necessary to make the trip, the planning index is used in determining the total travel time necessary for the trip. The planning time index is computed as the 95th percentile travel time divided by the average travel time.

In the context of the airport APM industry, it may not be expected that passengers would be traveling daily on an airport APM, nor that the travel time on an airport APM would vary to a degree great enough or frequent enough to make these measures meaningful for use by the public or an APM owner/operator. The additional time that must be allowed to make a trip within an established time, or the total time to be allowed for planning a trip within such a time, are measures that attempt to provide a level of predictability for a traveler using a (highway) system that presents a significant level of unreliability in travel times. Airport APM systems provide a relatively high level of travel time reliability that may make other measures better candidates for measuring performance.

2.5.2 National Transportation Operations Coalition

In 1999 the FHWA initiated the National Dialogue on Transportation Operations to encourage discussions on roadway operations issues and advocate for a stronger focus on operating the nation's transportation system. This resulted in several major initiatives and evolved into the creation of the National Transportation Operations Coalition (NTOC).

The NTOC is supported by the FHWA and serves as an important foundation for institutionalizing management and operations in the transportation industry. It is an alliance of national associations, practitioners, and private-sector groups that represent the collective interests of stakeholders at state, local, and regional levels who have a wide range of experience in operations, planning, and public safety. The mission of the NTOC is "to improve management and operation of the nation's existing transportation system so that its performance will exceed customer expectations" [2.5.8].

The Performance Measurement and Reporting subcommittee of the NTOC is one of a number of subcommittees and action teams working to promote operations strategies and benefits to stakeholders. In July 2005 this subcommittee issued a final report on its Performance Measurement Initiative, which identified 12 performance measures commonly agreed upon by federal, state, and local transportation officials to be the basis for a national set of performance measures. The measures may be used for internal management, external communications, and comparative measurement. The measures are:

- Customer satisfaction
- Extent of congestion – spatial
- Extent of congestion – temporal
- Incident duration
- Nonrecurring delay
- Recurring delay
- Speed
- Throughput – person
- Throughput – vehicle
- Travel time – link
- Travel time – reliability (buffer time)
- Travel time – trip

Of these 12, there are four that may be appropriately used as performance measures in the airport APM industry: customer satisfaction, incident duration, throughput – person, and throughput – vehicle. Each of these is briefly discussed in the following paragraphs with regard to applicability to airport APMs.

2.5.2.1 Customer Satisfaction

Customer satisfaction is a measure in the NTOC Performance Measurement Initiative final report that applies specifically to highway management and operations; however, it is a measure that can be applied in the airport APM industry as well. It can be measured in different ways, one of which is by assigning values to survey responses and tracking those values over time. While the literature review of APM-related material did not specifically yield customer satisfaction as a measure used in the airport APM industry, it is a measure that merits further exploration and may possibly be found to be in use at airport APM properties today.

2.5.2.2 Incident Duration

The second NTOC performance measure that may be applicable to the airport APM industry is the incident duration measured in median minutes per incident. While this measure has specific definition and meaning in the NTOC report as applied to the highway industry, a similar measure is in use today in the airport APM industry, as described earlier in this appendix. MTTR, or mean time to restore, is a measure that similarly gauges the time elapsed from the beginning until the end of an incident or failure and is used in the overall calculation of system availability. Where this measure is used to evaluate the effectiveness of emergency responders on incident duration in the highway industry, it can and is similarly used to evaluate the maintainability and effectiveness of maintenance technicians on failures in the airport APM industry.

2.5.2.3 Throughout

The remaining two NTOC performance measures that may be applicable to the APM industry are the measures of person and vehicle throughput. Both are measures of capacity and are currently used in the design and operations of airport APM systems. For the most part, they are very well defined in the APM industry. As discussed earlier in this appendix, capacity is taken into account during revenue operations of airport APM systems in general and as a way to credit operators who provide the highest capacity during degraded mode operations. It will be useful to further explore the potential use of capacity as a performance measure for airport APM systems.

2.5.3 Freeway Performance Measurement: NCHRP Project 3-68

The final area of highway performance measurement is discussed in this section and concerns the final report and guidebook of NCHRP Project 3-68, "Guide to Effective Freeway Performance Measurement," produced as *NCHRP Web-Only Document 97: Guide to Effective Freeway Performance Measurement* [2.5.6].

The report recommends a total of 47 measures in 12 categories as core freeway performance measures, and an additional 78 measures in nine categories as supplemental freeway performance measures.

The research team focused on the core performance measures and found several that were the same as or similar to measures previously discussed in this section of the appendix. As such, those are not reconsidered here. However, there are three measures that were found to merit exploration in terms of their applicability to airport APMs: vehicle miles of travel (VMT), safety, and energy consumption.

2.5.3.1 Vehicle Miles of Travel

Vehicle miles of travel is the product of the number of vehicles traveling over a length of freeway times the length of the freeway. This measure is also used in the APM industry, except that it is based on the distance the vehicles travel over the length of the revenue areas of the system guideway. The numbers of fleet miles and/or average annual vehicle miles are used regularly in the development of fleet sizes, maintenance and storage facility sizes, preventive maintenance schedules, and cost estimates for operations and maintenance of APM systems. Although the research of airport APM literature performed for this memorandum did not reveal performance measures employing a vehicle- or fleet-mile component, it may nevertheless be useful in comparing airport APM systems. For example, annual fleet mileage may be useful as a standalone measure to describe an APM system as compared to other APM systems. A measure incorporating vehicle mileage could also be useful, such as the number of platform door failures per vehicle mile traveled.

2.5.3.2 Safety

The core measures listed for safety (quality of service) in the report for NCHRP Project 3-68 specifically apply to crashes (i.e., total crashes, fatal crashes, overall crash rate, fatality crash rate, and secondary crashes). Any measurement related to crashes would not be applicable to the APM industry since crashes almost never occur. However, there are some safety measures that may merit further exploration for airport APMs. It has been the experience of the research team that airport APMs, although intrinsically very safe, may result in passenger injury when the system is not used correctly. Such isolated instances occur when trains perform an emergency braking while passengers are not either seated or holding onto a stanchion, handrail, or strap, and when platform or vehicle doors close on passengers that attempt to enter or exit a train after the warning chime has sounded and the doors have begun to move. These instances are the reasons most often cited when litigation is involved. Some safety measures that may be interesting to track in these contexts are the number of emergency brakings per thousand interstation runs performed and the number of door closing alarms per thousand dwell sequences. These safety-related measures may be useful in gauging the risk of exposure to passenger injuries for these isolated instances. Theoretically, the higher the value of the measure, the greater the risk of exposure. The lower the value of the measure, the lower the risk of exposure.

2.5.3.3 Fuel Consumption per Vehicle Mile Traveled

The report recommends a performance measure of fuel consumption per VMT, which is calculated based on the modeled gallons of fuel consumed on a freeway divided by the freeway VMT. A variation of this measure may be useful in the APM industry. Because APM systems use electrical energy rather than fuel (gas/diesel) energy, the corresponding measure would be electrical energy consumption per vehicle mile traveled. Designers today use this measure as part of the process of estimating O&M costs for APM systems. It remains to be seen, however, if this measure would be useful beyond that. This measure may be relevant in the measurement of freeway performance because roadway vehicles often can be standing still or creeping in bumper-to-bumper congestion. As congestion gets worse, the measure would theoretically reflect that (i.e., the gallons of fuel consumed would increase while VMT decreases). Although APM systems consume electrical energy when standing still, the systems are not susceptible to the type of congestion and delays seen on freeways, and because of this, it is not expected that this measure as applied to airport APM systems would be meaningful.

2.6 Conclusion

It is undeniable that automated people movers are playing a vital role in various airports and activity centers around the world. APM systems transport people from their origin to destination with a high degree of reliability, comfort, and speed. Given their importance, it is essential for APM operators and decision makers to evaluate and manage their systems using a set of performance measures.

The base of literature on transportation performance measures of other modes is large, especially when compared with that of APM systems. With the long history of developing, improving, and applying performance indicators in the transportation planning and operations fields, transit performance measures, for example, are fairly comprehensive in covering efficiency, effectiveness, and customer perspectives. On the other hand, performance measurement methodologies are still evolving, and there is no uniformly compiled framework for various agencies due to the diversity of systems and their respective service areas. Nevertheless, the material reviewed in preparation of this appendix served as a road map for the project team to develop the guidebook for performance measures of airport APM systems.

SECTION 3

Appendix A Bibliography

3.1 Performance Measurement—In General

[2.1.1] Chang, H. W., R. D. Banker, and W. W. Cooper. "Simulation Studies of Efficiency and Returns to Scale with Nonlinear Functions in DEA," *Annals of Operations Research,* 1995.

[2.1.2] Charnes, A., W. Cooper, and E. Rhodes. "Measuring the Efficiency of Decision-Making Units." *European Journal of Operational Research,* 1978.

[2.1.3] Chu, X., G. J. Fielding, and B. W. Lamar, "Measuring Transit Performance Using Data Envelopment Analysis." California University, Irvine, 1990.

[2.1.4] Federal Highway Administration. Office of Operations. Performance Measurement Fundamentals. http://ops.fhwa.dot.gov/perf_measurement/fundamentals.htm. Accessed October 2007.

[2.1.5] Government Accountability Office. United States of America. *Performance Measurement and Evaluation: Definitions and Relationships.* GAO-05-739SP. May 2005.

[2.1.6] Henderson, G., P. Kwong, and H. Adkins. "Regularity Indices for Evaluating Transit Performance." *Transportation Research Record 1297.* TRB, National Research Council, Washington, D.C., 1991, pp. 3–9.

[2.1.7] Kaplan, R., and D. Norton. "The Balanced Scorecard: Measures that Drive Performance." *Harvard Business Review.* Vol. 70, Issue 1, Jan/Feb 1992, pp. 71–79.

[2.1.8] Lee, D. B., "Transit Cost and Performance Measurement." *Transport Reviews,* Vol. 9, No. 2. Taylor & Francis Limited, 1989.

[2.1.9] Litman, T. 2005. "Measuring Transportation: Traffic, Mobility and Accessibility." *The ITE Journal,* Vol. 73, No. 10, October 2003, pp. 28–32.

[2.1.10] Liu, R., R. Pendyala, and S. Polzin. "A Simulation of the Effects of Intermodal Transfer Penalties on Transit Use." *Transportation Research Record 1623.* TRB, National Research Council, Washington, D.C., 1998, pp. 88–95.

[2.1.11] National Partnership for Reinventing Government. *Balancing Measures: Best Practices in Performance Management.* August 1999. http://govinfo.library.unt.edu/npr/library/papers/bkgrd/balmeasure.html. Accessed October 2007.

[2.1.12] National Performance Review. *Serving the American Public: Best Practices in Performance Measurement. Benchmarking Study Report.* June 1997. http://govinfo.library.unt.edu/npr/library/papers/benchmrk/nprbook.html. Accessed October 2007.

[2.1.13] Obeng, K. "Total Productive Measurement in Bus Transit: Comment." *Journal of Transportation Engineering,* Vol. 117, No. 6. American Society of Civil Engineers. 1991.

[2.1.14] Phillips, J. K. "An Application of the Balanced Scorecard to Public Transit System Performance Assessment." *Transportation Journal*, Vol. 43, No. 1. American Society of Transportation and Logistics, 2004.

[2.1.15] Racca, D. P. "Transportation Network Models to Accurately Estimate Transit Level of Service (Paper 1921)," *Proceedings of the Twenty-Fourth Annual ESRI User Conference.* 2004.

[2.1.16] Takyi, I. K. "A Multi-Dimensional Methodology for Evaluating Public Transportation Services." *Transportation Research. Part A: Policy and Practice,* Vol. 27, No. 5., Pergamon Press plc; Elsevier, 1993.

3.2 APMs

[2.2.1] American Society of Civil Engineers. *Automated People Mover Standards—Part 1.* American Society of Civil Engineers, Reston, VA, 2006.

[2.2.2] Anderson, J. E. "Dependability as a Measure of On-Time Performance of Personal Rapid Transit Systems." *Journal of Advanced Transportation,* 26, 1992, Institute for Transportation, Inc.

[2.2.3] Chicago O'Hare International Airport. AGT System Technical Provisions. Undated.

[2.2.4] Chicago O'Hare International Airport. How to Count the Availability. 1993.

[2.2.5] Cottrell, W. D., and Y. J. Nakanishi. "Airport APM Performance Measurement: Network Configuration and Service Availability." 11th International Conference on Automated People Movers, Apr. 2007, American Society of Civil Engineers. Vienna.

[2.2.6] Dallas–Fort Worth International Airport. APM System Operations and Maintenance General Conditions (Conformed), November 2000.

[2.2.7] Elms, C. P. "Defining and Measuring Service Availability for Complex Transportation Networks." International Conference on PRT & Other Emerging Transportation Systems, Nov. 1996. Minneapolis.

[2.2.8] Frey, H., and A. Levy. "An Incentive Approach to Contractual Availability for Downgraded Operation." 9th International Conference on Automated People Movers, Sept. 2003, ALONEX/Aeroports de Paris. Singapore.

[2.2.9] Gosling, G. D., and L. Xiao-Yun. "Modeling Measures to Improve Intermodal Connectivity At Airports." University of California at Berkeley, 2006.

[2.2.10] Greater Orlando Aviation Authority, Orlando International Airport. Phase II Expansion, Automated Guideway Transit System, Part 4—O&M Contract Provisions. 1987.

[2.2.11] Howell, J. K. "RAM: Reliability, Availability, and Maintainability of APM Systems." 2nd International Conference on Automated People Movers, March 1989, American Society of Civil Engineers. Miami.

[2.2.12] Lede, N. W., and L. Yu. *A Manual for Evaluating Personalized Public Transit Systems.* Federal Transit Administration, Texas Southern University, and Dallas Area Rapid Transit, 1992.

3.3 Public Transit

[2.3.1] American Public Transit Association. "Transit Performance and Productivity 1975–1980: Improvements Through the Inter-Governmental Partnership." American Public Transit Association, 1985

[2.3.2] Dzurik, A. A., and W. T. Olsen. "Development of Transit System Productivity Measures Based on Section 15 and Urban Area Environment Data." Florida State University, Tallahassee; Urban Mass Transportation Administration, 1985.

[2.3.3] Fielding, G. J. *Managing Public Transit Strategically.* Jossey-Bass, San Francisco, 1987.

[2.3.4] Hensher, D. A., and R. Daniels. "Productivity Measurement in the Urban Bus Sector." *Transp. Policy,* 2-3, 1995, pp. 179–194.

[2.3.5] Hooper, P. G., and D. A. Hensher. "Measuring Total Factor Productivity of Airports: An Index Number Approach." *Transp. Res.* Part E, 33-4, 1997, pp. 249–259.

[2.3.6] Hobeika, A. G., C. Kanok-Kantapong, and T. K. Tran. "A Methodology for Comparative Transit Performance Evaluation with UMTA Section 15 Data." *Transportation Research Record 961.* TRB, National Research Council, Washington, D.C., 1984, pp. 36–43.

[2.3.7] Kopp, J. C., J. A. Moriarty, and M. E. Pitstick. "Transit Attractiveness: Systematic Approach to Transit Performance Measurement." *Transportation Research Record 961.* TRB, National Research Council, Washington, D.C., 1986, pp. 11–16.

[2.3.8] Lauritzen, T. "Chicago Transit Authority Special Service Performance Measures for First Year of Service." *Proceedings of Metropolitan Conference on Public Transportation Research.* Sponsored by Center for Urban Research and Policy Studies, 1987.

[2.3.9] Lew, L. L., J.-L. Li, and M. Wachs. "Comprehensive Transit Performance Indicators." Working paper. Institute of Transportation Studies, School of Public Policy and Social Research, University of California at Los Angeles, 1994.

[2.3.10] Lyons, W. M., E. Weiner, and P. Shadle. "Comparative Evaluation of Performance of International Light Rail Systems," *Transportation Research Record 1433.* TRB, National Research Council, Washington, D.C., 1994. pp. 115–122.

[2.3.11] Meyer, M. D. "Use of Performance Measures for Surface Transportation in Different Institutional and Cultural Contexts: Cases of Australia, Japan, and New Zealand." *Transportation Research Record: Journal of the Transportation Research Board, No. 1924.* Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 163–174.

[2.3.12] National Transit Database Program. Welcome to the National Transit Database. http://www.ntdprogram.gov/ntdprogram/ntd.htm. Accessed October 2007.

[2.3.13] National Transit Database Program. *2007 Safety and Security Reporting Manual.* http://www.ntdprogram.gov/ntdprogram/pubs/safetyRM/2007/HTML/2007_Safety_and_Security_Reporting_Manual_TOC.htm. Accessed October 2007.

[2.3.14] National Transit Database Program. Welcome to NTD Data. http://www.ntdprogram.gov/ntdprogram/pubs/national_profile/2005NationalProfile.pdf. Accessed October 2007.

[2.3.15] Rouphail, N. M., "Performance Evaluation of Bus Priority Measures in the Chicago Loop." *Proceedings of Metropolitan Conference on Public Transportation Research.* Sponsored by Center for Urban Research and Policy Studies, 1986.

[2.3.16] Rystam, A., and H. Renolen. "Evaluation of Public Transport Measures: Guidelines for Evaluation on a Common Basis." Swedish Transport and Communications Research Board, 1998.

[2.3.17] Tanaboriboon, Y., A. S. M. Abdul Quium, and C. Changsingha. "Performance Indicator Analysis: A Management Tool for the Improvement of Bus Transit Operations in Bangkok." *Journal of Advanced Transportation,* Vol. 27, No. 2. Institute for Transportation, 1993.

[2.3.18] Topp, R. M., "Improving Light Rail Transit Performance in Street Operations: Toronto Case Study." In *State of the Art Report 2.* TRB, National Research Council, Washington, D.C., 1985, pp. 227–233.

[2.3.19] Transportation Research Board, Kittelson and Associates, Incorporated. *TCRP Report 88: A Guidebook for Developing a Transit Performance Measurement System.* Transportation Research Board of the National Academies, Washington, D.C., 2003.

[2.3.20] Committee for the Conference on Performance Measures to Improve Transportation Systems and Agency Operations. *Conference Proceedings 26: Performance Measures to Improve Transportation Systems and Agency Operation: Report of a Conference.* Transportation Research Board of the National Academies, Washington, D.C., 2001.

[2.3.21] Turnbull, K. F. *Conference Proceedings 36: Performance Measures to Improve Transportation Systems: Summary of the Second National Conference.* Transportation Research Board of the National Academies, Washington, D.C., 2005.

[2.3.22] Vaziri, M., and J. A. Deacon. "Peer Comparisons in Transit Performance Evaluation." *Transportation Research Record 961.* TRB, National Research Council, Washington, D.C., 1984, pp. 13–21.

3.4 Airlines

[2.4.1] Aviation Consumer Protection Division, Office of Aviation Enforcement and Proceedings, US Department of Transportation. *Air Travel Consumer Report.* http://airconsumer.ost.dot.gov/reports/index.htm. Accessed September 2007.

[2.4.2] Bureau of Transportation Statistics. Performance Measures in the Airline Industry. http://www.bts.gov/programs/airline_information/performance_measures_in_the_airline_industry. Accessed September 2007

[2.4.3] Federal Aviation Administration. Preliminary Accident and Incident Reports. http://www.faa.gov/data_statistics. Accessed September 2007.

[2.4.5] Federal Aviation Administration. Runway Safety, Historical Data and Statistics. http://www.faa.gov/runwaysafety/stats.cfm. Accessed September 2007.

[2.4.6] Federal Aviation Administration. Runway Safety. http://www.faa.gov/runwaysafety. Accessed September 2007.

[2.4.7] Fruin, J. J. *Pedestrian Planning and Design.* Revised edition. Mobile: Elevator World, Inc., 1987.

[2.4.8] International Air Transport Association. *Airport Development Reference Manual.* 9th ed. Montreal: IATA, 2004.

[2.4.9] International Civil Aviation Organization, *International Standards and Recommended Practices for Facilitation,* Annex 9. 9th edition. ICAO, 2006.

[2.4.10] Massachusetts Port Authority (Massport). Press release, 2/15/2001. http://www.massport.com/about/press01/press_news_performance.html. Accessed September 2007

3.5 Highways

[2.5.1] Federal Highway Administration. *Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation: Final Report.* Cambridge Systematics, Inc., and Texas Transportation Institute. September 2005.

[2.5.2] Federal Highway Administration. Office of Operations. National Transportation Operations Coalition. http://www.ops.fhwa.dot.gov/nat_dialogue.htm. Accessed October 2007.

[2.5.3] Federal Highway Administration. Office of Operations. The National Transportation Operations Coalition. http://www.ops.fhwa.dot.gov/aboutus/one_pagers/ntoc.htm. Accessed October 2007.

[2.5.4] Federal Highway Administration. *Travel Time Reliability: Making it There on Time, All the Time.* Cambridge Systematics, Inc., and Texas Transportation Institute. http://www.ops.fhwa.dot.gov/publications/tt_reliability/TTR_Report.htm. Accessed February 2006.

[2.5.5] Federal Highway Administration. Office of Operations. *Operations Performance Measurement.* http://www.fhwa.dot.gov/aboutus/one_pagers/perf_measurement.pdf. FHWA-OP-04-039. Accessed April 2004.

[2.5.6] Cambridge Systematics, Inc., Texas Transportation Institute, University of Washington, and Dowling Associates. *NCHRP Web-Only Document 97: Guide to Effective Freeway Performance Measurement: Final Report and Guidebook.* Transportation Research Board of the National Academies, Washington, D.C., 2006. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w97.pdf. Accessed August 2006.

[2.5.7] National Transportation Operations Coalition. *Performance Measurement Initiative: Final Report.* Accessed July 2005.

[2.5.8] National Transportation Operations Coalition. Performance Measures. http://www.ntoctalks.com. Accessed October 2007.

SECTION 4

Survey Plan and Instrument (Task 3)

Task 3 of the research requires the following work:

Develop a detailed plan for a survey to investigate the current practice of performance measurement by APM systems at airports. The survey should (1) address the characteristics of the APM systems, (2) determine the performance measures used, (3) identify the data-collection practices associated with the performance measures, (4) request performance data for the most recent year, and (5) request suggestions for improving data-collection and performance-measurement practices. The detailed plan should include a survey instrument and a list of airports to be included in the survey. The plan is not to be executed until the panel has reviewed and approved the final survey plan.

The objectives of the survey plan were to:

- Describe the process of developing the survey instrument;
- Describe the steps taken to implement the survey;
- Transmit the draft survey instrument; and
- Obtain ACRP and panel approval of the survey plan and instrument prior to its implementation.

The following sub-sections document the results of the work undertaken for Task 3 of the research.

4.1 Survey Sites and Site Visits

In conjunction with developing the first version of the survey instrument, the team identified APM systems to be surveyed and those APM sites that would be visited, in accordance with the scope of work and panel comments and in support of finalizing the draft of the survey instrument.

4.1.1 Identify Candidate APM Systems to Survey

The scope of work for ACRP Project 03-07 originally envisioned surveying all airport APM systems worldwide. Prior to contract award and in consideration of project budget and schedule constraints, ACRP limited the survey to North American airport APM systems. In addition, proposal review comment number 5 provided by the panel on March 12, 2007, recommended that the survey "at a minimum, include all airport APMs in North America and several non-airport APMs to obtain data from at least 10 airports and two non-airport APMs." With this in mind, the research team began the process of identifying the APM systems to be surveyed as well as those to be visited during development of the survey instrument.

The Airfront.21 information clearinghouse maintains a list of all APM systems operating throughout the world. Systems are classified as airport, airfront, leisure, institutional, line transit, and local transit. The list of North American APM systems in Table A-3 is excerpted from Airfront.21 and provides a starting point for the current research project.

4.1.2 Select Final APM Systems to Survey

The research team analyzed the list of North American APM systems in Table A-3 and, based in part on the scope of work, selected 31 systems to survey. All North American airport APM systems were selected to be surveyed. Nine non-airport APM systems were also selected based on those systems' size and operation, a cross section of technologies, and a number likely to result in receiving the minimum two responses requested by the panel. The research team generally did not include low-volume, leisure, and institutional systems in its selection of non-airport systems.

The final lists of airport and non-airport APM systems selected to be surveyed are provided in Tables A-4 and A-5, respectively.

4.1.3 Select APM Systems for Site Visits

After finalizing the list of APM systems to be surveyed, the research team analyzed the characteristics and geographic

Table A-3. North American APM systems.

Airport		**Leisure**	
	Atlanta		Bellagio-Monte Carlo APM – Las Vegas, NV
	Chicago		Bronx Zoo Monorail – New York City, NY
	Cincinnati		CalExpo
	Dallas–Fort Worth		Circus-Circus – Reno, NV
	Denver		Hershey Park – PA
	Detroit		Mandalay Bay/Excalibur Tram – Las Vegas, NV
	Houston (2)		Mud Island River Park – Memphis, TN
	Las Vegas		Miami Metrozoo Monorail – FL
	Mexico City		Minneapolis Zoo Monorail – MN
	Miami		Mirage/Treasure Island Tram – Las Vegas, NV
	Minneapolis (2)		Primm Valley UniTrak – NV
	Newark		Primm Valley Shuttle System (Whiskey Pete) – NV
	New York City – JFK Airport	**Institutional**	
	Orlando		Clarian People Mover – Indianapolis, IN
	Pittsburgh		Duke Hospital – Raleigh, NC
	San Francisco		Getty Center Tram – Los Angeles, CA
	Seattle-Tacoma		Huntsville Hospital Tram System – AL
	Tampa (2)		Las Colinas APT – Irving, TX
	Toronto		Morgantown PRT – WV
Local Transit			Pearlridge Center Monorail – Honolulu, HI
	Detroit, MI PeopleMover		Senate Subway – Washington, DC
	Jacksonville, FL Skyway	**Line Transit**	
	Las Vegas Monorail – NV		Vancouver SkyTrain – British Columbia, Canada
	Miami, FL Metromover		
	Scarborough RT – Toronto, Canada		

Source: Airfront.21 at http://www.airfront.us/PDFs/Count07.pdf

Table A-4. North American airport APM Systems to be surveyed.

	Airport	System Name	Technology	Propulsion	Wheel/Rail Interface
1	Atlanta (ATL)	Concourse People Mover	People mover (large)	Onboard	Rubber/concrete
2	Chicago (ORD)	Airport Transit System	People mover (large)	Onboard	Rubber/steel
3	Cincinnati (CVG)	n/a	People mover (medium)	Cable	Hovair/concrete
4	Dallas–Fort Worth (DFW)	Skylink	People mover (large)	Onboard	Rubber/concrete
5	Denver (DEN)	Auto. Gdwy Transit Sys.	People mover (large)	Onboard	Rubber/concrete
6	Detroit (DTW)	Express Tram APM	People mover (medium)	Cable	Hovair/concrete
7	Houston (IAH)	TerminaLink	People mover (large)	Onboard	Rubber/concrete
8	Houston (IAH)	Inter-Terminal Train	People mover (small)	LIM	Polypropylene/steel
9	Las Vegas (LAS)	C and D Gates Tram	People mover (large)	Onboard	Rubber/concrete
10	Mexico City (MEX)	n/a	People mover (medium)	Cable	Rubber/steel
11	Miami (MIA)	Concourse E Shuttle	People mover (large)	Onboard	Rubber/concrete
12	Minneapolis (MSP)	Concourse Tram	People mover (medium)	Cable	Steel/steel
13	Minneapolis (MSP)	Hub Tram	People mover (medium)	Cable	Hovair/concrete
14	New York City (JFK)	AirTrain JFK	Rapid Rail (medium)	LIM	Steel/steel
15	Newark (EWR)	AirTrain Newark	Monorail (small)	Onboard	Rubber/steel
16	Orlando (MCO)	n/a	People mover (large)	Onboard	Rubber/concrete
17	Pittsburgh (PIT)	n/a	People mover (large)	Onboard	Rubber/concrete
18	San Francisco (SFO)	AirTrain	People mover (large)	Onboard	Rubber/concrete
19	Seattle-Tacoma (SEA)	Satellite Transit System	People mover (large)	Onboard	Rubber/concrete
20	Tampa (TPA)	n/a	People mover (large)	Onboard	Rubber/concrete
21	Tampa (TPA)	Garage Monorail	Monorail (small)	Onboard	Rubber/steel
22	Toronto (YYZ)	The LINK	People mover (medium)	Cable	Rubber/steel

Note: Table A-4 was updated and edited by Lea+Elliott, Inc. for the purposes of this report.

Table A-5. North American non-airport APM systems to be surveyed.

	City	System Name	Technology	Propulsion	Wheel/Rail Interface
1	Detroit, MI	Detroit People Mover	Rapid rail (small)	LIM	Steel/steel
2	Indianapolis, IN	Clarian People Mover	People mover (small)	Onboard	Rubber/concrete
3	Jacksonville, FL	Skyway	Monorail (small)	Onboard	Rubber/concrete
4	Las Vegas, NV	Las Vegas Monorail	Monorail (medium)	Onboard	Rubber/concrete
5	Las Vegas, NV	Mandalay Bay–Excalibur Tram	People mover (medium)	Cable	Rubber/steel
6	Miami, FL	Metromover	People mover (large)	Onboard	Rubber/concrete
7	Morgantown, WV	Morgantown PRT	PRT	Onboard	Rubber/concrete
8	Vancouver, BC	SkyTrain	Rapid rail (medium)	LIM	Steel/steel
9	Washington, DC	US Senate Subway	People mover (small)	LIM	Polypropylene/steel

Table A-6. APM systems at which to conduct site visits.

APM System	Type	Layout
Toronto (YYZ)	Airport	Dual-lane shuttle
Detroit (DTW)	Airport	Single lane bypassing shuttle
Detroit, MI	Non airport	Single-lane loop
Chicago (ORD)	Airport	Pinched loop
Newark (EWR)	Airport	Pinched loop
New York City (JFK)	Airport	Pinched loop (trunk/branches) and single loop
Vancouver, BC	Non airport	Pinched loop (trunk/branches)
Seattle-Tacoma (SEA)	Airport	Single-lane loop (2) and single-lane shuttle
Seattle, WA*	Non airport	Dual-lane shuttle
Dallas–Fort Worth (DFW)**	Airport	Dual-lane loop

*The Seattle Center Monorail, although a manually operated people mover, was selected for a site visit since the research team was also visiting the APM at Seattle–Tacoma International Airport.

**The Dallas–Fort Worth Skylink APM, although not visited specifically for the purpose of this project, is listed here as a site visit since one of the research team members is very familiar with the system, having worked on the implementation of that APM over a multiyear period.

locations of the systems in the list to determine the preferred properties for conducting site visits. The general purpose of the site visits was to gain a better understanding of the different APM systems, thereby helping to structure the survey instrument. The research team's goal was to visit, in the fewest number of trips, as many diverse systems as possible within the constraints of the project budget. Table A-6 shows systems that were selected for site visits.

4.2 Survey Instrument

Concurrent with identifying sites to be surveyed and visited, the team developed the survey instrument and presented an early form of it to the APM systems where site visits took place. The instrument was then refined based on feedback from those visits and other information observed/obtained as a result of the visits.

4.2.1 Develop Survey Instrument

In preparing for the site visits, the research team developed a draft survey instrument based on the project scope of work, the tasks performed on the project up to that point, and its own experience planning, designing, operating, and maintaining APM systems. The draft survey instrument was completed in advance of the site visits and contained questions organized in the following five areas: performance measures, data collection, suggestions for improving airport APM performance measures, general information, and system and operating characteristics.

4.2.2 Conduct Site Visits

Concurrent with the development of the draft survey instrument, the research team scheduled visits at the APM systems listed in Table A-6. While coordinating the schedule, the team corresponded with the hosts to explain the purpose of the visits and the objectives they wished to accomplish while there, which included a system tour and discussion with the hosts about aspects of their system and performance measurement practices. The team conducted its site visits in two trips, as reflected in Tables A-7 and A-8.

During the site visits, the research team provided a copy of the team's scope of work (the ACRP RFP) to the hosts. The team also provided a copy of the draft survey instrument for the purposes of obtaining comments on the instrument from the owner/operator perspective. These comments, in conjunction with the information gleaned from the site

Table A-7. Trip #1 site visits.

	System			
Location	Type	Name	Date Visited	Host*
Toronto (YYZ)	Airport	The LINK	12-03-07, a.m.	Mr. M. Riseborough, GTAA
Detroit (DTW)	Airport	Express Tram	12-03-07, p.m.	Mr. D. Farmer, NWA
Detroit, MI	Non-airport	Detroit People Mover	12-04-07, a.m.	Ms. B. Hansen, DTC
Chicago (ORD)	Airport	Airport Transit System	12-04-07, p.m.	Mr. R. Rambhajan, OATS
Newark (EWR)	Airport	AirTrain Newark	12-05-07, p.m.	Ms. J. Giobbie, PANY&NJ
New York City (JFK)	Airport	AirTrain JFK	12-06-07, a.m.	Mr. H. McCann, PANY&NJ

*GTAA = Greater Toronto Airports Authority; NWA = Northwest Airlines; DTC = Detroit Transportation Corporation; OATS = O'Hare Airport Transit System; PANY&NJ = Port Authority of New York & New Jersey

Table A-8. Trip #2 site visits.

	System			
Location	Type	Name	Date Visited	Host*
Vancouver, BC	Non-airport	SkyTrain	12-10-07, a.m.	Mr. C. Morris, BC Rapid Transit
Seattle–Tacoma (SEA)	Airport	Satellite Transit System	12-11-07, a.m.	Mr. T. O'Day, Port of Seattle
Seattle, WA	Non-airport	Seattle Center Monorail	12-11-07, p.m.	Mr. G. Barney, Seattle Monorail Svcs

*BC Rapid Transit = British Columbia Rapid Transit Company

visits themselves, assisted the team in developing the survey instrument.

The research team rode the systems and toured the maintenance shops and control centers during each of the visits. The team was also able to obtain a large amount of information from the owners/operators through their comprehensive presentation of the systems as well as their answers to the many questions asked by the research team members. In some cases, the hosts provided preliminary performance measurement reports and data for the team to take with them.

4.2.3 Finalize Survey Instrument

Based on the information collected during the visits and from the host's comments obtained on the instrument, the research team updated the draft survey at the conclusion of the site visits.

It became apparent during development of the draft survey and site visits that a separate survey instrument for airport and non-airport APM systems would be more appropriate since certain questions for an airport APM system may not apply to a non-airport APM system. While the differences between the surveys were not expected to be substantial, the team decided to implement different surveys, which also enabled the team to provide a clearer explanation to the non-airport APM systems as to the reasons for their inclusion in a project about airport APM performance measurement.

4.3 Survey Plan

The plan for implementing the survey of airport and non-airport APM systems is described in the following steps.

4.3.1 Step 1: Distribute Introductory Letter

In the first step of the survey, the research team sent a letter to the chief executive of each system to introduce the research team, the project's scope of work, and the objectives of the project and survey. The letter informed the recipients that a member of the team would be calling them within the following week to inquire as to their willingness to participate in the survey.

4.3.2 Step 2: Determine Willingness to Participate in Survey

In the second step of the survey, the research team contacted by telephone the chief executive of each system to discuss the introductory letter and any questions they may have had and determine whether they were willing to complete a survey of their system. For those that agreed to participate, the team obtained the participant's email address to which the survey could be distributed.

The research team tracked the systems that agreed to participate and proceeded with subsequent steps once all responses were obtained.

4.3.3 Step 3: Report to ACRP Panel on Participation Ratio

In the third step of the survey, the research team notified the ACRP Senior Program Officer (SPO) and panel of the participation ratio on the survey.

Once it was known that at least 50% of the systems were willing to participate in the survey, the team immediately notified the SPO and panel that the participation ratio had reached that level. The team then proceeded with Step 4.

4.3.4 Step 4: Distribute Survey

In the fourth step of the survey, the research team distributed via email the survey instrument attached to a letter containing a synopsis of the survey categories, instructions on how and where participants could forward their survey responses and other material, the date that responses were desired, and other information relevant to completing the survey.

The survey instrument was in an electronic format that the participants could complete on their computers and send back via email attachment or print out and complete by hand. In the survey cover letter, participants were given the option of returning responses and accompanying material via email, upload to an FTP site, or delivery service to the research team at the project's cost.

4.3.5 Step 5: Verify Receipt of Survey

In the fifth step of the survey, the research team contacted the survey participants by telephone approximately 4 days after distribution of the survey to verify that the survey had been received. During the call the team inquired if the recipients had had the opportunity to review the survey, if there were any questions, and if they were still intending to participate. This provided an opportunity to determine the recipients' reaction to the survey and make adjustments early in the process, if necessary.

4.3.6 Step 6: Receive Survey Responses

In the sixth step of the survey, the research team began to receive responses from participants, organize the data, and perform analysis by identifying the similarities and differences in the data.

4.3.7 Step 7: Survey Follow-Up

In the seventh step, the research team contacted by telephone the survey participants that had not yet provided responses to ensure that they had not encountered any difficulties with the survey. The call was made by the end of the third week from the date the survey was distributed.

The team also contacted survey participants by telephone and email with any outstanding questions resulting from the responses that were received. These contacts were made as was necessary once responses were received and questions had arisen.

Where participants were having problems answering questions, the team assisted by providing clarification(s) and sharing responses from other owners/operators. In cases where there were multiple questions and/or time constraints and a face-to-face meeting was more efficient, the team coordinated with the participant in answering survey questions on site.

4.3.8 Step 8: Report to ACRP Panel on Response Ratio

In the eighth step of the survey, the research team notified the SPO and panel of the response ratio on the survey.

4.3.9 Step 9: Compile Data and Clarify Responses

In the ninth step of the survey, the research team continued to compile survey responses and other data and contacted participants to clarify responses where necessary.

4.3.10 Step 10: Transmit Thank-You Letters to Respondents

In the tenth and final step of the survey, the research team distributed thank-you letters to the participants that provided responses to the survey.

SECTION 5

Survey Implementation and Data Analysis (Task 4)

Task 4 of the research required the following work:

Conduct the survey developed in Task 3 and compile the survey findings. In addition to compiling the survey results, the researchers should identify similarities and differences in defining performance measures and data among APM systems at airports. For example, APM systems at airports currently define grace periods and downtime in different ways.

The following subsections document the results of the work undertaken for Task 4 of the research.

5.1 Survey Implementation

The research team surveyed 31 North American APM systems (all 22 airport systems in North America and nine non-airport systems) in accordance with the survey plan described in Section 4. Fourteen of the 22 airport APM systems returned survey responses, and four of the nine non-airport APM systems returned survey responses. This represents participation rates of 64% for airport APM systems, 44% for non-airport APM systems, and an overall participation rate of 58%, exceeding the 50% participation rate desired by the ACRP panel. With 14 airport APM systems and four non-airport APM systems participating, the minimum quantity of APM systems participating also exceeded the panel-recommended numbers of 10 airport APM systems and three non-airport APM systems.

In summary, the surveys contained the following questions, organized in the five sections described in the following and provided in Section 6 of this Appendix.

5.1.1 Section 1: General Information

1. What is the name of your APM system?
2. What is the location of your system?
3. Who is the owner of the system?
4. Who is the operator of the system, contracted or otherwise? What was the basis for their selection?
5. Who is the maintainer of the system, contracted or otherwise? What was the basis for their selection?
6. Who is the supplier of the system elements (e.g., the vehicles, automatic train control equipment, guideway running surfaces)? What was the basis for their selection?
7. What functions at your system are contracted by the owner (and what functions are subcontracted by the contracted system operator or maintainer, if applicable)?
8. What is the number of operations and maintenance personnel required to operate and maintain the system?
9. When did your system first open to the public?
10. Who can we contact with questions about your survey responses? Please provide a name, title, and contact information (telephone and email address).

5.1.2 Section 2: Performance Measures

1. What performance measure(s) do you use to judge overall performance of your system? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, and formulas. Please attach, upload, or send material as necessary to explain this answer.
2. What performance measure(s) do you use for contractual compliance purposes? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, formulas, and interpretations, including how rigorous the contract is followed and any modifications of the contract that may have been made. Please attach, upload or send material, including any applicable contract sections, to explain this answer.

3. Please describe every instance in which you allow a grace period (e.g., at schedule transitions, during incidents, for late trains), the duration of each grace period, and its effect on calculation of performance measures such as system availability. Please attach, upload, or send material as necessary to explain this answer.
4. Please describe the instances in which you allow credit for partial service, including how it is calculated and its associated definitions, rules, and formulas. Please attach, upload, or send material as necessary to explain this answer.
5. What performance measure(s) do you use to judge subsystem and/or component performance? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, and formulas. Please attach, upload, or append material as necessary to explain this answer.
6. What safety-related performance measure(s) do you track? Please attach, upload, or append material as necessary to explain this answer.
7. What security-related performance measure(s) do you track? Please attach, upload, or append material as necessary to explain this answer.
8. What performance measure(s) do you use to judge efficiency and/or effectiveness in general, and in particular, the economic efficiency and/or effectiveness at your system? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, and formulas. Please attach, upload, or append material as necessary to explain this answer.
9. What performance measure(s) do you use to judge the passenger experience at your system? Please describe each measure, including their names, how they are calculated, their associated definitions, rules, and formulas, and the frequency of collection from passengers. Please attach, upload, or append material as necessary to explain this answer.
10. What other performance measure(s) is in use at your system that you have not already provided? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, and formulas. Please attach, upload, or append material as necessary to explain this answer.
11. What data do you collect (that is not already collected for the measures you have provided previously) that could be used as a performance measure? Please append material as necessary to explain this answer.
12. Which of the measures that you have provided previously best represents your system's performance from the passenger's perspective (i.e., what measure is best at representing impacts on your system's passengers)?
13. How does your system affect overall airport performance? In response to this question, please consider the following:
    A. Is your system the only form of transportation from which passengers can choose, or is an alternative form/mode of transportation available while your system is operating (such as walking, automobiles/taxis, buses)?
    B. How disruptive to airport performance is it when your system is unavailable? For example, would the airport continue to perform fairly well during a shutdown because passengers can get to areas served by your system by other means (such as walking), or would the loss of your system have a major adverse impact on airport performance (because buses would have to be called in, for example)? Please describe if such an outage affects only part of the airport (e.g., one concourse) or if it affects the entire airport (e.g., all terminals, parking facilities, rental cars).
14. What operating strategies do you employ to improve the performance of your system?
15. What equipment capabilities or configurations that do not exist in your system today would improve its performance if they were implemented? Please describe how these would improve performance.

5.1.3 Section 3: Data Collection

1. What methods do you use to collect and report data for the performance measures provided previously? Please attach, upload, or send any procedures that may describe collection and reporting of data at your system.
2. Please attach, upload, or append examples of the daily, monthly, and annual data collection forms and reports that you currently use.
3. Please provide quantitative data that describes the performance of your system in 2007, using the performance measures you have described previously. Please attach, upload, or append material as necessary to explain this answer.

5.1.4 Section 4: Suggestions for Improving APM Performance Measures

1. Please provide any plans you may have regarding ways to improve your own data collection and performance measuring process. Please attach, upload, or append material as necessary to explain this answer.

2. Please provide any suggestions you may have for improving data collection and performance measurement practices among airport APM systems, including what you see as being the best set of performance measures common to all or most (airport or non-airport) APM systems. Please attach, upload, or append material as necessary to explain this answer.
3. Please provide your thoughts on any measures you consider to be poor measures of (airport or non-airport) APM performance and why.

5.1.5 Section 5: System and Operating Characteristics

1. What is the configuration/layout of your system?
2. Does your system have bidirectional functionality (i.e., can a vehicle operate in full automatic mode in both directions)? On the mainline? In the yard/storage areas?
3. Please attach, upload, or send the following information if available:
   A. System or route map
   B. Track map
4. What type of passengers does your APM transport? [This question was left blank for the non-airport APM survey.]
5. In what type of environment does your system operate?
6. What areas does your system serve? [This question was left blank for the non-airport APM survey.]
7. What are the operating modes of your system?
8. What is the length of your system's guideway? (total without maintenance and storage/yard guideway and total of maintenance and storage/yard guideway length)
9. Is it possible at your system for passengers to initiate their own exit from a train and egress onto the guideway or walkway without the assistance of O&M staff or other life safety personnel? If no, why not?
10. How many evacuations has your system experienced? Please count the number of evacuations by incident. For example, if multiple trains are evacuated during the same incident, that would be considered one evacuation. Please indicate the numbers of each of the following for both 2007 and the last 3 years:
    A. Passenger-initiated evacuations.
    B. Operator-initiated evacuations.
    C. Total evacuations.
    D. Total unsupervised evacuations.
11. Does your system have automatic sliding platform doors at stations? Please indicate the numbers of each of the following for both 2007 and the last 3 years:
    A. Number of platform door failures preventing passengers from using a vehicle.
    B. Total number of platform door failures.
    C. Number of vehicle door failures preventing passengers from using a vehicle.
    D. Total number of vehicle door failures.
12. How many stations and platforms does your system have? What is the average dwell time?
13. What type of propulsion system does your system use?
    A. Nominal operating voltage and current?
14. What type of vehicle conveyance and track running equipment is employed at your system?
15. What locations are monitored by a video surveillance system (closed circuit television equipment), and how is the information managed?
16. How many cars make up the smallest independently operated vehicle that can be operated in your system? For example, a married pair would be considered two cars for the purposes of this survey.
17. What is the configuration of the operating fleet used in typical daily operations?
18. What is the number of peak operating vehicles and trains required for an average operating weekday at your system?
19. What is the total number of vehicles in your fleet?
20. How is the coupling/uncoupling function managed at your system?
21. What is the location of the vehicle maintenance facility at your system? If possible, please provide a drawing, plan, or map of the maintenance facility and yard area, as well as its location in relation to your overall system.
22. How many hours is your system scheduled to operate? How many hours did your system operate in 2007? (If an on-demand system, how many hours per day is the system scheduled to be available for use?)
23. How many on-guideway maintenance and recovery vehicles (MRVs) does your system have? How many incidents have occurred in your system where an in-service vehicle needed to be pushed/pulled by the MRV or another vehicle?
24. What is your system's average weekday operating schedule?
25. What is the passenger capacity of a vehicle at your system? Please describe how this is determined (i.e., if it is obtained from the initial vehicle specification or technical proposal, through visual observation or passenger counts during peak periods, or some other method). Please provide as much detail as possible about the capacity of your vehicles.
26. Do passengers use luggage carts (e.g., Smarte Carte) on board your vehicles? If so, does the capacity number provided in question 25 take this into account? [This question was left blank for the non-airport APM survey.]
    A. How does the use of luggage carts on your vehicles affect your vehicle capacity? Please quantify this if possible.

27. What is the capacity of your system?
28. How is the system operation and operating schedule managed at your system?
29. What is the total number of vehicle (fleet) miles accrued at your system in 2007?
30. What is the total number of in-service vehicle (fleet) hours accrued at your system in 2007?
31. What is the total number of passenger trips taken on your system in 2007? Please indicate how this number is obtained (e.g., through fare gate information, ticket sales, or other passenger counting systems, or if it is an estimate based on parking data, airline passenger data, or other external data).
32. Are passengers charged a fare to use your system? If yes, please indicate the fare and basis.

5.1.6 Section 6: Cost

1. What are the costs to operate and maintain your system?

5.1.7 Section 7: Other

1. Please provide any additional information about your system or (airport or non-airport) APM performance measures that might not have been covered by the previous survey questions that you believe could be useful to our research.

5.2 Survey Response Data, Compilation, and Analysis

The data received from survey participants were comprehensive in total. The research team generated a simple categorical overview of responses based largely on the structure of the survey questionnaire, summarized in Section 5.1 and provided in Chapter 6. Since some responses to survey questions are either not complete or are missing, some data are not reported here but otherwise provide the reader with a substantial understanding of airport APM systems and their associated performance measurement systems. Data within the report are referred to by generic APM system IDs rather than by an identifiable APM system name. The treatment of data in this manner (as confidential) was ensured in order to obtain the highest rate of participation in the surveys and the most comprehensive levels of data.

5.2.1 Age of Airport APM Systems Surveyed

Of the 14 airport APM system participants responding to the survey, two have been in service since the early 1970s and are the earliest implementations of APM systems in North America. The other systems reflect opening dates in the 1990s and after. A quick scan of projects under construction or in the planning stages reveals that five new airport APM systems in North America will be inaugurated in the next three years (Trans.21, "Current APM Implementations: Fall, 2008." APM Guide Online).

The four participating non-airport APM systems surveyed opened in 1986, 1987, 1997, and 2003.

5.2.2 System and Operating Characteristics

Response data from the system and operating characteristics portion of the survey were distilled and are reported on the following pages. As can be seen from the reported data, a majority of the airport APM systems are pinched loop systems, have four or more stations, are less than 3 miles in length, operate outdoors, operate 24 hours per day, operate in a continuous mode, operate on a peak headway of less than 300 sec, transport non-secure passengers, use rubber-tire vehicles running on concrete or steel, and are designed to operate at a propulsion power supply voltage and current of 600VAC.

Half of the airport APM survey participants provided ridership data for 2007. Of those seven, six based their passenger counts on airline data, parking data, random sampling, or some other estimate. Only one airport APM system had counts taken from an automatic passenger counting system installed within the APM system. The remaining seven airport APM systems participating in the survey provided no passenger counts. The research indicates that passenger counting for airport APM systems is mostly performed manually, when that data is collected. Annual passenger trips (2007) for the seven airport APM systems participating in the survey ranged from about 3,000 to about 15 million.

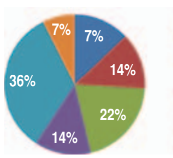
All four of the non-airport APM systems participating in the survey have in place a means to count passengers, with three of them using automatic collection methods. The 2007 annual ridership for these properties ranged from about 620,000 to 2.3 million.

In comparison to the characteristics of the airport APM survey data, the non-airport APM survey data for the system and operating characteristics showed that a large majority of those systems have eight or more stations, are greater than 2½ miles in length, operate 17 to 19 hours daily, operate on a peak headway of less than 200 sec, use rubber running tires on concrete, and operate in a continuous mode. All of the surveyed non-airport APM systems responded that the systems are outdoors and have average dwell times of 30 sec or less.

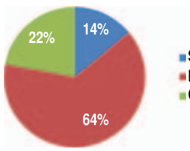
Figures A-1 through A-8 provide a synthesis of the survey response data received by the research team from both the airport and non-airport APM systems participating in the survey.

	AIRPORT APM SYSTEM IDs													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
System Configuration	Dual-lane shuttle	Single-lane shuttle; 2 single loops	Pinched loop	Pinched loop	Pinched loop	Pinched loop	Pinched loop	Dual-lane shuttle	Single-lane bypassing shuttle	Double loop	Single-lane by passing shuttle	Double loop	Dual-lane shuttle	Single-lane shuttle
APM Passenger Type	Non-secure	Combination	Non-secure	Non-secure	Combination	Non-secure	Non-secure	Non-secure	Secure	Non-secure	Secure	Secure	Non-secure	Non-secure
APM Environment	Outdoors	Indoors	Indoors	Outdoors	Indoors	Outdoors	Outdoors	Indoors	Indoors	Outdoors	Outdoors	Outdoors	Outdoors	Outdoors
System Operating Mode	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Combined	Continuous	Continuous	Combined	Continuous	Continuous	Continuous

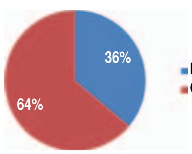
System Configuration



APM Passenger Type



APM Environment



System Operating Mode

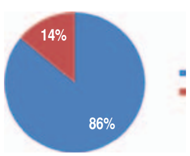
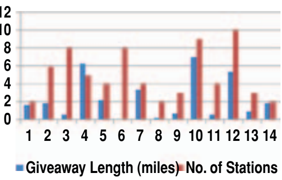
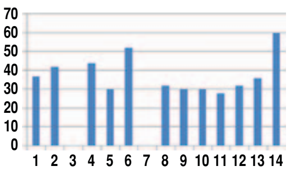
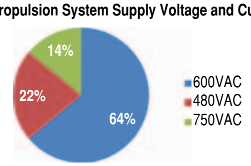


Figure A-1. Airport APM systems characteristics #1.

	AIRPORT APM SYSTTEM IDs													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Guideway Length (miles) and No. of Stations	1.62 miles 16 stations	1.87 miles 6 stations	0.55 miles 8 stations	6.30 miles 5 stations	2.17 miles 4 stations	Data missing 8 stations	3.36 miles 4 stations	0.21 miles 2 stations	0.72 miles 3 stations	7.00 miles 9 stations	0.50 miles 4 stations	5.42 miles 10 stations	0.92 miles 3 stations	1.88 miles 2 stations
Average Dwell Time (sec)	37	42	Data missing	44	30	45 to 60	Data missing	32	30	30	28	32	36	60
Propulsion System Supply Voltage and Current	600VAC	600VAC	480VAC	750VDC	600VAC	600VAC	600VAC	480VAC	600VAC	600VAC	480VAC	750VDC	600VAC	600VAC
Vehicle Conveyance and Track Running Equipment	Rubber tire on concrete; onboard motor(s)	Rubber tire on concrete; onboard motor(s)	Rubber tire on steel; onboard motor(s)	Rubber tire on steel; onboard motor(s)	Rubber tire on concrete; onboard motor(s)	Rubber tire on steel; onboard motor(s)	Rubber tire on concrete; onboard motor(s)	Hovair over concrete; wayside motor(s)	Hovair over concrete; wayside motor(s)	Rubber tire on concrete; onboard motor(s)	Steel wheel on steel rail; wayside motor(s)	Rubber tire on concrete; onboard motor(s)	Rubber tire on steel; wayside motor(s)	Rubber tire on steel; wayside motor(s)







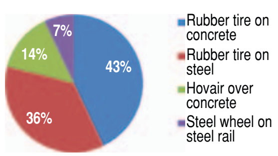
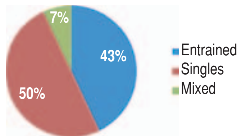
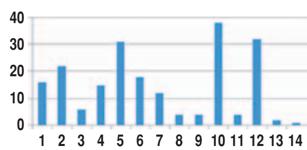
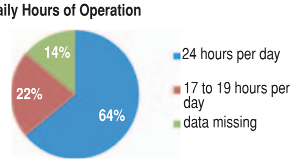


Figure A-2. Airport APM systems characteristics #2.

	AIRPORT APM SYSTEM IDs													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Operating Fleet Configuration		Mixed	Singles	Entrained	Entrained	Singles	Entrained	Entrained	Entrained	Singles	Entrained	Singles	Singles	Singles
Total Fleet	16	22	6	15	31	18	12	4	4	38	4	32	2	1
Daily Hours of Operation	24	24	24	24	Data missing	24	24	24	17 to 19	Data missing	17 to 19	24	24	17 to 19
PeakHeadway (sec)	90	180	30	310	20	45 to 60	Data missing	114	210	150	213	149	240	670







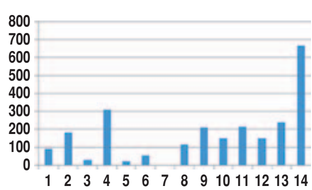


Figure A-3. Airport APM systems characteristics #3.

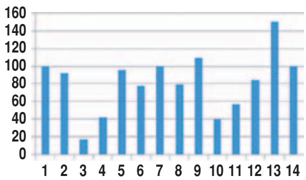
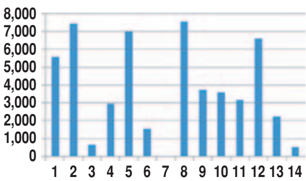
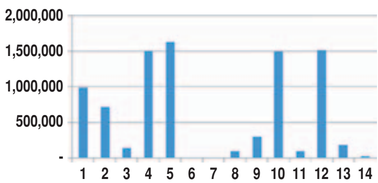
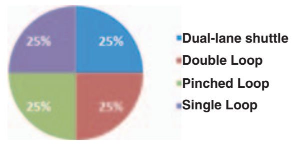
	AIRPORT APM SYSTEM IDs													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Vehicle Capacity (no. of passengers per vehicle) 	100	92	17	57 to 85	96	78	100	60 to 97	218	40	47 to 67	69 to 99	150	100
Line Capacity (pphpd) 	5,600	7,452	680	2,962	7,000	1,560	Data missing	7,578	3,737	3,600	3,177	6,624	2,250	537
Annual Fleet Miles (2007) 	992,000	717,087	146,000	1,152,913	1,633,415	Data missing	Data missing	93,888	301,148	1,500,000	98,184	3,031,245	185,310	28,828

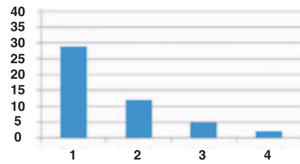
Figure A-4. Airport APM systems characteristics #4.

	NON-AIRPORT APM SYSTEM IDs			
	1	2	3	4
System Configuration	Double loop	Single loop	Pinched loop	Dual-lane shuttle
Total Fleet	29	12	5	2
APM Environment	Outdoors	Outdoors	Outdoors	Outdoors
System Operating Mode	Continuous	Continuous	Continuous	Combined

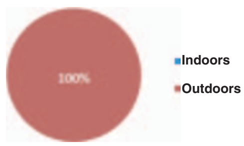
System Configuration



Total Fleet



APM Environment



System Operating Mode

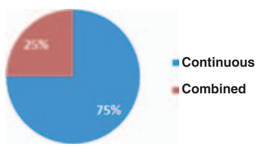


Figure A-5. Non-airport APM systems characteristics #1.

5.2.3 O&M Cost

O&M costs were reported by eight of the 14 airport APM survey participants and ranged from $1.02M to $15.39M annually. Although the survey requested specific breakdowns for cost data, many properties reported rolled-up costs. Table A-9 shows the annual O&M costs reported by the airport APM survey participants:

O&M costs were reported by two of the four non-airport APM survey participants. Annual O&M costs for the two non-airport APM systems that did not report such data were obtained from the National Transit Database. Table A-10 shows the annual O&M costs for the non-airport APM survey participants:

5.2.4 Performance Measures

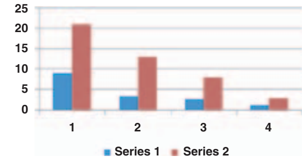
Survey response data collected from the performance measures section of the surveys are provided in Tables A-11 and A-12 for airport and non-airport APM survey participants, respectively, and categorized as follows:

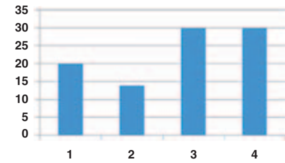
- Overall performance measures (including contractual performance measures),
- Safety and security performance measures,
- Efficiency/effectiveness performance measures,
- Passenger experience performance measures,
- Other performance measures,
- Grace periods,
- Partial service,
- Other data collected as performance measures, and
- Best performance measures from the passenger's perspective.

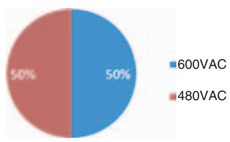
The data show that availability is overwhelmingly the most common performance measure used to judge system performance, being used by 13 of the 14 airport APM systems and by all four of the non-airport APM systems.

The data also reflect that grace periods and partial service credit are used in determining availability for almost all of the airport APM systems but are much less prevalent for the non-airport APM systems.

	NON-AIRPORT APM SYSTEM IDs			
	1	2	3	4
Guideway Length (miles) and No. of Stations	9.03 miles 21 stations	3.40 miles 13 stations	2.80 miles 8 stations	1.40 miles 3 stations
Average Dwell Time (sec)	20	30	14	30
Propulsion System Supply Voltage and Current	600VAC	600VAC	480VAC	480VAC
Vehicle Conveyance and Track Running Equipment	Rubber tire on concrete onboard motor(s)	Steel wheel on steel rail; linear induction motor(s)	Rubber tire on concrete; linear induction motor(s)	Rubber tire on concrete; onboard motor(s)







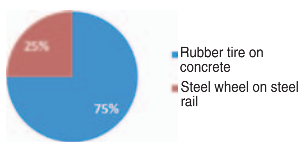
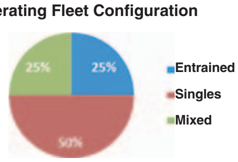
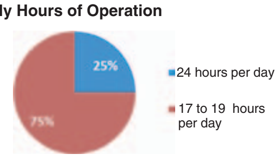


Figure A-6. Non-airport APM systems characteristics #2.

	NON-AIRPORT APM SYSTEM IDs			
	1	2	3	4
Operating Fleet Configuration	Mixed	Entrained	Singles	Singles
Daily Hours of Operation	17 to 19	17 to 19	17 to 19	24
Peak Headway (sec)	180	150	190	450





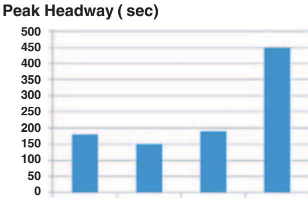


Figure A-7. Non-airport APM systems characteristics #3.

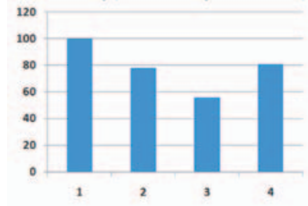
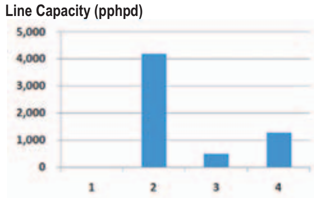
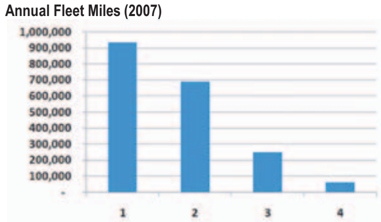
	NON-AIRPORT APM SYSTEM IDs			
	1	2	3	4
Vehicle Capacity (no. of passengers per vehicle) 	100	78	56	81
Line Capacity (pphpd) 	Data missing	4,200	500	1,296
Annual Fleet Miles (2007) 	934,906	692,309	252,944	63,931

Figure A-8. Non-airport APM systems characteristics #4.

Table A-9. Airport APM systems annual O&M costs.

Airport APM System	Annual O&M Cost		Remarks
	FY 07/08 Budgeted	FY 06/07 Actual	
A	$4.4M	—	power not included
B	$10.93M	$10.18M	
C	$8.5M	$8.0M	
D	$2.23M	$2.17M	
E	$1.05M	$1.02M	
F	$1.81M	$1.49M	power not included
G	$2.01M	$1.88M	power not included
H	$15.39M	$13.95M	includes all O&M costs

Table A-10. Non-airport APM systems annual O&M costs.

Non-Airport APM System	Annual O&M Cost		Remarks
	FY07/08 Budgeted	FY06/07 Actual	
A	—	$4.61M	includes all O&M costs
B	—	$21M	includes all O&M costs
C	$19.04M	$21.29M	includes all O&M costs
D	—	$0.97M	power not included

Table A-11. Airport APM systems performance measures.*

	AIRPORT APM SYSTEM IDs													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Overall performance measures	System availability	Availability; days without service interruption	System availability	System availability	System availability		System availability; DT events	System availability; DT events	Reliability; maintainability; availability	System availability; DT events	System availability; DT events	System availability; DT events	Reliability; maintainability; availability	Reliability; maintainability; availability
Safety and security performance measures	—	Occurrences tracked (safety) and logged (security)	—	Employee and passenger injuries	Occurrences logged	OSHA occurrences tracked; Security occurrences logged	Fires and injuries tracked	Emergency stops logged	Occurrences logged	Occurrences reported	Emergency stops logged	Safety occurrences monitored	Occurrences reported	Occurrences reported
Efficiency/effectiveness performance measures	Cost/pax trip	KWH per vehicle mile	Cost/pax trip	System availability	—	—	Operating hours per vehicle; riders per month	Operating miles/ lane/headways; operating hours	—	—	Operating miles/ lane/headways; operating hours	Pax/car-hour; cost/pax; cost/car-mile	Maintainability	Cost per pax trip
Passenger experience performance measures	Cleanliness; friendliness of staff; ride quality and comfort; complaints; responsiveness to complaints; convenience	Availability	Cleanliness; friendliness of staff; ride quality and comfort; complaints; responsiveness to complaints; convenience	—	Comments cards received from passengers	Station and train announcements	Cleanliness; friendliness of staff; responsiveness to events; station and train announcements; complaints	Complaint cards received from passengers	Comments and feedback from passengers and employees	passenger surveys; complaints; observations; audits	Complaint cards received from passengers	Wait time; trip time; in-service inspections	—	—
Other performance measures	DT events (when exceeded, affect availability)	Occurrences of interruptions and incidents	DT events (when exceeded, affect availability)	Ridership	—	System availability; DT events; QA audits	Maintenance completion; staff training	Round trip time; station availability	—	PM schedule inspection adherence	Round trip time; station availability	Cost/car-hour; car-hour per employee; op. hours/$1 cost	PM/CM completions; breakdowns	PM/CM completions; breakdowns
Grace periods	Yes, for stoppages equal to or less than 1 min and 10 alarms or less of 1 min in duration or less	—	Yes, extensive and specific grace periods allowed relative to delays and downtime events	Yes, for late trains up to 21 sec and for schedule transitions up to 15 min	Yes, for service interruptions up to 3 min	Yes, for delays up to 5 min; for delays and failures up to 1 min (fleet and platform doors)	Yes, no more than 2 min during schedule transitions	Yes, for operational transitions up to 2 min plus one headway	Yes, for downtime up to one round trip time	Yes, up to 1 headway (mode); up to 2X headway (fleet); up to 1 min (platform)	Yes, for operational transitions up to 2 min plus one headway	Yes, up to 1 headway (mode); up to 2X headway (fleet); up to 1 min (platform)	Yes, for first 10 unrelated malfunctions, up to 1 headway; up to one service day for one door blockage	Yes, for first 10 unrelated malfunctions, up to 1 headway
Partial service credit	Yes, for vehicle HVAC unit(s) OTS; car LED graphics OTS; doors blocked; and 1-car of a 2-car train blocked	—	Yes, for scheduled train(s) OTS, station(s) OTS, and vehicle HVAC unit(s) OTS	Yes, if actual capacity >½ the scheduled capacity and the actual headways <2 X scheduled headway	—	Yes, K factors applied depending on actual mode operated vs. mode scheduled	Yes, K factor if time allotted for schedule transition is exceeded	Yes, K factors applied depending on actual mode operated vs. mode scheduled	Yes, for liquidated damages; monetary penalty factored according to failure type	Yes, K factors applied when exceeding schedule transition time; and for lesser mode operated	Yes, K factors applied depending on actual mode operated vs. mode scheduled	Yes, K factors applied when exceeding schedule transition time; and for lesser mode operated	Yes, proportional to capacity provided vs. scheduled capacity	Yes, proportional to capacity provided vs. scheduled capacity
Other data collected as performance measures	—	Car mileage	—	—	—	—	—	Average headways/miles	Vehicle trips; mileage	—	Average headways/miles	PM schedule tracking	Stoppages and DT	Shutdowns; ridership
Best measures from passenger's perspective	Convenience	Availability	Convenience	System Availability	Comments card	DT events and durations	System availability	DT events	Maintainability	System availability	DT events	DT events	Availability	Shutdowns

*Pax = passengers, DT = downtime, QA = quality assurance, KWH = kilowatt hours, K = partial service factor, PM/CM = preventive maintenance/corrective maintenance, OTS = out of service

Table A-12. Non-airport APM systems performance measures.

	NON-AIRPORT APM SYSTEM IDs			
	1	2	3	4
Overall performance measures	System availability; reliability (time and distance); peak vehicles	System availability	Train availability; schedule adherence	System availability
Safety and security performance measures	Occurrences tracked	Occurrences tracked		
Efficiency/effectiveness performance measures		Cost/mile; cost/hour; cost/trip; cost/pax mile; etc.	Operating hours per employee	
Passenger experience performance measures	Complaints per month	Number of complaints	Cleanliness; elevator and escalator in service; and complaints	
Other performance measures	Subsystem failures graphed; scheduled vs. unscheduled maintenance; inactive vehicles/ scheduled peak vehicles			
Grace periods			Yes, train may be late for up to one min	Yes, delays up to 5 min
Partial service credit		Credit given for what is operated		
Other data collected as performance measures		Daily ridership data	System shutdowns and service interruptions	
Best measures from passenger's perspective	Fleet reliability and peak vehicles		Service interruptions	

For the airport APM system survey participants, safety and security performance measures exist in large part via occurrences logged and reported but not tracked. This is different for the non-airport APM system participants that are FTA-mandated reporters. They log, report, and track all safety and security incidents as required for the National Transit Database. The differences in the approaches can be explained not only by the mandated reporting aspect for FTA properties, but also by the frequency and nature of the safety and security incidents that occur in airport versus non-airport APM systems. For the airport APM system survey participants, safety incidents are generally limited to slips, falls, and/or other minor injuries that are reported to and handled by the owner's risk management department. Security incidents are also somewhat minor, being limited to crimes such as vandalism, which are reported to and handled by the local airport or city police. This is contrasted with the more frequent and diverse types of safety and security incidents that can be associated with public transit in urban environments.

In terms of economic efficiency and/or effectiveness measures, four of the 14 airport APM system survey participants reported tracking an economic measure of this type. The limited use of this type of measure could be explained by the distributed nature of O&M cost responsibility for airport APM systems. Often a contractor is responsible for one function or aspect of the APM system (operations and/or maintenance of systems and/or facilities), whereas the owner or other contractors are responsible for other functions or aspects. Similarly, traction power and other APM utilities costs can often be rolled up in other owner utilities costs, making it more difficult to ascertain the costs allocated to the APM. Collecting and allocating airport APM-only O&M costs can therefore become somewhat challenging.

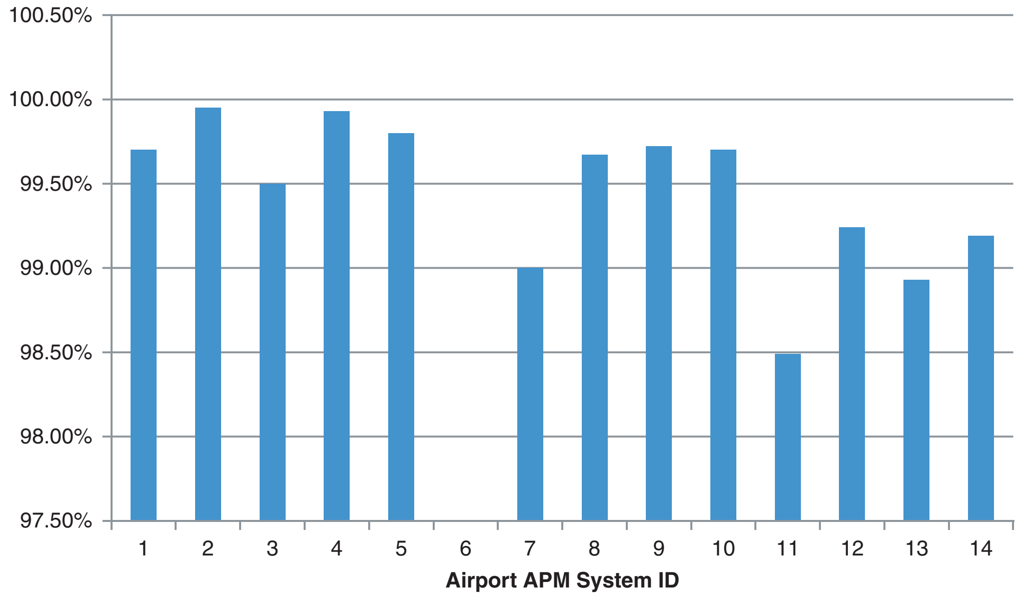


Figure A-9. Airport APM systems availability values.

Passenger-experience performance measures appeared to be in large part tracked according to passenger complaints and/or comments for both the airport APM and non-airport APM survey participants.

5.2.5 Data Collection

The collection of data for airport APM system survey participants is largely accomplished automatically using data received via supervisory control and data acquisition (SCADA) and control center computer system equipment. Manual collection of data is typically involved when passenger surveys and counts are required or when data not collected automatically by the system, such as narrative descriptions of incidents, need to be entered for reporting purposes.

The reported quantitative availability performance data for the airport APM survey participants are reported in Figure A-9. The same data for the non-airport APM survey participants were provided by two of the four participants and reported at 92% and 99%.

5.2.6 Suggestions for Improving Airport APM Performance Measures

Both airport and non-airport APM survey participants provided suggestions on how to improve airport APM performance measures and data collection in that effort. The suggestions included:

- Use nonproprietary systems for data collection;
- Standardize training and certification of personnel working in airport APM systems;
- Improve availability calculation since it is too vague;
- Improve communication with passengers;
- Improve definitions of "fully functioning vehicle" and when a door is "available";
- Improve the user interface for the proprietary reporting tool;
- Improve fault tracking database;
- Incorporate automatic passenger counting systems into stations during initial construction of the system;
- Ensure automatic passenger counting is reported directly to control center;
- Use on-time performance to measure overall performance and reserve availability to refer to the fleet;
- Have all airport APM systems use service availability and the same formula [MTBF/(MTBF+MTTR)];
- Use fleet, mode, and station door availability, as well as duration and number of downtime events to measure performance;
- Use a train control software package in the industry that creates performance data automatically.

SECTION 6

Airport APM Survey

Survey Section 1: General Information

Question 1.1

What is the name of your APM system?

Question 1.2

What is the location of your system?

Airport Name:

City, State/Province:

Question 1.3

Who is the owner of the system?

Owner:

Address:

City, State/Province, Zip:

Contact Name:

Office Phone:

email:

Question 1.4

Who is the operator of the system, contracted or otherwise? What was the basis for their selection?

Operator:

Address:

City, State/Province, Zip:

Contact Name:

Office Phone:

email:

Basis for Selection:

Question 1.5

Who is the maintainer of the system, contracted or otherwise? What was the basis for their selection?

Maintainer:

Address:

City, State/Province, Zip:

Contact Name:

Office Phone:

email:

Basis for Selection:

Question 1.6

Who is the supplier of the system elements (e.g., the vehicles, automatic train control equipment, guideway running surfaces)? What was the basis for their selection?

Subsystem	**Supplier**
1. Vehicle:	____________
2. Automatic Train Control System:	____________
3. Power Distribution System:	____________
4. Guideway Running/Guidance Eqp.:	____________

Basis for Selection:

Question 1.7

What functions at your system are contracted by the owner (and what functions are subcontracted by the contracted system operator or maintainer, if applicable)?

Examples of contracted or subcontracted functions include the following:

Operations	Vehicle maintenance
Wayside maintenance	All maintenance
Engineering	Vehicle cleaning
Security	Station attendants
Facilities maintenance	Other

Question 1.8

What is the number of operations and maintenance personnel required to operate and maintain your system?

	Bargaining Unit Personnel (FTEs)	Non-Bargaining Unit Personnel (FTEs)
1. Management:	________	________
2. Administration:	________	________
3. Ops—Control Center:	________	________
4. Ops—Service Agts:	________	________
5. Ops—Other:	________	________
6. Maint.—Vehicle:	________	________
7. Maint.—Track:	________	________
8. Maint.—ATC/Power:	________	________
9. Maint.—Facilities/Plant:	________	________
10. Warehouse/Stores:	________	________
11. Engineering:	________	________
12. Other:	________	________
13.	________	________
14.	________	________
15.	________	________

Note: FTE = full-time equivalent

Question 1.9

When did your system first open to the public?

Question 1.10

Who can we contact with questions about your survey responses? Please provide a name, title, telephone number, and email address.

Survey Section 2: Performance Measures

Question 2.1

What performance measure(s) do you use to judge **overall** performance of your system? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, and formulas. Please attach, upload, or send material as necessary to explain this answer.

Examples of these measures include but are not limited to:

System reliability	Travel time
System maintainability	Wait time
System availability	Trip time
System dependability	Round trip time
Operational headway	Line capacity
Platform headway	Punctuality
Station dwell time	Missed stations
Missed trips	On-time performance

Question 2.2

What performance measure(s) do you use for contractual compliance purposes? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, formulas, and interpretations, including how rigorous the contract is followed and any modifications of the contract that may have been made. Please attach, upload, or send material, including any applicable contract sections, to explain this answer.

Question 2.3

Please describe every instance in which you allow a grace period (e.g., at schedule transitions, during incidents, for late trains), the duration of each grace period, and its effect on calculation of performance measures such as system availability. Please attach, upload, or send material as necessary to explain this answer.

A grace period is generally described as the period of time when the system can be late or even unavailable to passengers and not be taken into account in the calculation of a particular system performance measure, such as system dependability, as long as the system is restored to its normal operating configuration and headway within that grace period.

Question 2.4

Please describe the instances in which you allow credit for partial service, including how it is calculated and its associated definitions, rules, and formulas. Please attach, upload, or send material as necessary to explain this answer.

Partial service credit is generally described as the credit given (usually in terms of the amount of time) to system unavailability when only partial or alternate service is provided during periods of downtime.

Question 2.5

What performance measure(s) do you use to judge subsystem and/or component performance? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, and formulas. Please attach, upload, or append material as necessary to explain this answer.

Examples of these measures include
but are not limited to:

Subsystem and/or component reliability [mean time, distance, or cycles between failure (MTBF)]
- Fleet reliability;
- Platform door reliability;
- Switch reliability;
- Elevator, escalator, moving walkway reliability;
- Automatic Train Control system reliability.

Subsystem and/or component maintainability [mean time to repair or restore (MTTR)]
- Fleet maintainability;
- Platform door reliability;
- Power distribution equipment maintainability;
- Elevator, escalator, moving walkway maintainability;
- Automatic Train Control system maintainability.

Subsystem and/or component availability (MTBF/MTBF + MTTR)
- Fleet availability;
- Platform door availability;
- Central control computer system availability;
- Elevator, escalator, moving walkway availability;
- Automatic train control system availability.

Question 2.6

What safety-related performance measure(s) do you track? Please attach, upload, or append material as necessary to explain this answer.

Examples of these measures include
but are not limited to:

Occurrences and/or rates of:

Collisions	Emergency brakings
Derailments	Fatalities
Fires	Suicides
Injuries	Train evacuations
Slips/trips/falls	Supervised
Caught in platform/vehicle doors	Unsupervised

Question 2.7

What security-related performance measure(s) do you track? Please attach, upload, or append material as necessary to explain this answer.

Examples of these measures include
but are not limited to:

Occurrences and/or rates of:

Fare evasion (as applicable)	Assault (aggravated and other)
Trespassing	Vandalism (including graffiti)
Bomb threats	Civil disturbances
Robbery	Larceny/theft
Burglary	

Question 2.8

What performance measure(s) do you use to judge efficiency and/or effectiveness in general, and in particular, the economic efficiency and/or effectiveness at your system? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, and formulas. Please attach, upload, or append material as necessary to explain this answer.

Examples of these measures include
but are not limited to:

Passenger trips per vehicle service mile
Passenger trips per vehicle service hour
Cost per vehicle service mile
Cost per vehicle service hour
Cost per train service mile
Cost per passenger mile
Cost per passenger trip
Operating hours per vehicle
Operating hours per employee
Maintainability (mean time to repair or restore)

Question 2.9

What performance measure(s) do you use to judge the passenger experience at your system? Please describe each measure, including their names, how they are calculated, their associated definitions, rules, and formulas, and the frequency of collection from passengers. Please attach, upload, or append material as necessary to explain this answer.

Examples of these measures include but are not limited to the following, and could be solicited in part via a passenger satisfaction survey:

Cleanliness
Ride quality/comfort
Responsiveness to complaints
Wait time
Trip time
Elevator, escalator, moving walkway performance
Friendliness of staff
Complaints
Convenience
Ease of wayfinding

Question 2.10

What other performance measure(s) is in use at your system that you have not already provided? Please describe each measure, including their names, how they are calculated, and their associated definitions, rules, and formulas. Please attach, upload, or append material as necessary to explain this answer.

Question 2.11

What data do you collect (that is not already collected for the measures you have provided previously) that could be used as a performance measure? Please append material as necessary to explain this answer.

Examples of this data include but are not limited to:

System shutdowns
Vehicle station stopping accuracy
Peak period vehicles or trains
Trips completed

Question 2.12

Which of the measures that you have provided previously best represents your system's performance from the passenger's perspective (i.e., what measure is best at representing impacts on your system's passengers)?

Question 2.13

How does your system affect overall airport performance? In response to this question, please consider the following:

A. Is your system the only form of transportation from which passengers can choose, or is an alternative form/mode of transportation available while your system is operating (such as walking, automobiles/taxis, buses)?

B. How disruptive to airport performance is it when your system is unavailable? For example, would the airport continue to perform fairly well during a shutdown because passengers can get to areas served by your system by other means (such as walking), or would the loss of your system have a major adverse impact on airport performance (because buses would have to be called in, for example)? Please describe if such an outage affects only part of the airport (e.g., one concourse) or if it affects the entire airport (e.g., all terminals, parking facilities, rental cars).

Question 2.14

What operating strategies do you employ to improve the performance of your system?

Examples of these strategies include
but are not limited to:

Operating entrained vehicles as opposed to independent vehicles
Operating in a pinched loop instead of on a shuttle or vice versa
Placing agents or attendants on board trains or at stations

Question 2.15

What equipment capabilities or configurations that do not exist in your system today would improve its performance if they were implemented? Please describe how these would improve performance.

Examples of these capabilities or configurations include but are not limited to:

Entrained vehicle operability
Pinched loop or shuttle configuration
More switches
Additional platforms at current stations
Platform screen doors
Redundant onboard control units
Platooning
Stub-end shop or storage tracks versus flow-through tracks

Survey Section 3: Data Collection

Question 3.1

What methods do you use to collect and report data for the performance measures provided previously? Please attach, upload, or send any procedures that may describe collection and reporting of data at your system.

Examples of these methods include but are not limited to:

Automatic collection by passenger counting systems
Automatic collection and reporting by the central control computer system
Manual collection by hand-filled passenger surveys
Manual collection by staff surveys/observations (owner or operator/maintainer)

Question 3.2

Please attach, upload, or append examples of the daily, monthly, and annual data collection forms and reports that you currently use.

Question 3.3

Please provide quantitative data that describes the performance of your system in 2007, using the performance measures you have described previously. Please attach, upload, or append material as necessary to explain this answer.

Survey Section 4: Suggestions for Improving Airport APM Performance Measures

Question 4.1

Please provide any plans you may have regarding ways to improve your own data collection and performance measuring processes. Please attach, upload, or append material as necessary to explain this answer.

Question 4.2

Please provide any suggestions you may have for improving data collection and performance measurement practices among airport APM systems, including what you see as being the best set of performance measures common to all or most airport APM systems. Please attach, upload, or append material as necessary to explain this answer.

Question 4.3

Please provide your thoughts on any measures you consider to be poor measures of airport APM performance and why.

Section 5: System and Operating Characteristics

Some questions in this section may be more easily answered using pictures and/or diagrams. Please attach, upload, or send this information to expand upon your system's characteristics as necessary.

Question 5.1

What is the configuration/layout of your system?

A. Single-lane shuttle
B. Single-lane bypassing shuttle
C. Dual-lane shuttle
D. Single loop
E. Double loop
F. Pinched loop
G. Multiple pinched loop (trunk/branch arrangement)
H. Other (please describe)

Question 5.2

Does your system have bidirectional functionality (i.e., can a vehicle operate in full automatic mode in both directions)?

A.	On the mainline:	YES	NO
B.	In the yard/storage areas:	YES	NO

Question 5.3

Please attach, upload, or send the following information if available:

A. System or route map
(An example could be the map provided to the traveling public in a pamphlet or at an online website.)
B. Track map
[An example could be the map on the train location screen in the control center, which reflects, in part, track layout and switch locations. (Hand sketches are perfectly acceptable.)]

Question 5.4

What type of passengers does your APM transport?

A. Secure
B. Unsecure
C. Sterile
D. Combination (please describe)

Question 5.5

In what type of environment does your system operate? Please indicate all that apply.

A. The system operates primarily or exclusively in an enclosed environment such as a building or tunnel.
B. The system operates primarily or exclusively outdoors.
C. The system is exposed to snow and ice during the winter months.
D. The system is exposed to 100°(F) days (or higher) during the summer months.

Question 5.6

What areas does your system serve?

A. Airline terminal(s) and/or concourse(s)
B. Rental car facilities
C. Public and/or employee parking
D. Public transit
E. Multimodal center
F. Other (please describe)

Question 5.7

What are the operating modes of your system?

A. Continuous
B. On demand
C. Combined
D. Other (please describe)

Question 5.8

What is the length of your system's guideway? Please state in single-lane units (feet or meters).

A. Total guideway length without maintenance and storage/yard guideway
B. Total maintenance and storage/yard guideway length

Question 5.9

Is it possible at your system for passengers to initiate their own exit from a train and egress onto the guideway or walkway without the assistance of O&M staff or other life safety personnel? If no, why not?

Question 5.10

How many evacuations has your system experienced? Please count the number of evacuations by incident. For example, if multiple trains are evacuated during the same incident, that would be considered one evacuation.

	In 2007	In the Last 3 Years
Passenger-initiated evacuations		
Operator-initiated evacuations		
Total evacuations		
Total unsupervised evacuations		

Question 5.11

Does your system have automatic sliding platform doors at stations?

A. YES
B. NO

	In 2007	In the Last 3 Years
Number of platform door failures preventing passengers from using a vehicle		
Total number of platform door failures		
Number of vehicle door failures preventing passengers from using a vehicle		
Total number of vehicle door failures		

Question 5.12

How many stations and platforms does your system have? What is the average dwell time?

A. Number of side platform stations: ________________
B. Number of center platform stations: ________________
C. Number of double platform stations: ________________
(platforms on both sides of a vehicle)
D. Number of triple platform stations: ________________
E. Other (please describe) ________________
F. Total number of stations: ________________
G. Total number of platforms: ________________
H. What is the average dwell time: ________________

Question 5.13

What type of propulsion system does your system use?

Nominal operating voltage: ________________ Current: AC or DC

A. Onboard propulsion—traction motors (please indicate motor type)
   AC or DC
B. Wayside propulsion—cable (please indicate grip type)
   Fixed grip or Detachable grip
C. Linear induction motors
D. Other (please describe)

Question 5.14

What type of vehicle conveyance and track running equipment is employed at your system?

A. Steel wheel on steel rail
B. Rubber tire on concrete running surface
C. Rubber tire on steel running surface
D. Other (please describe)

Question 5.15

What locations are monitored by a video surveillance system (closed circuit television equipment), and how is the information managed? Please check the boxes that apply.

	Real-Time Monitoring Capability	Record/Playback Capability
Maintenance/control facility		
Yard area		
Station platforms		
Escalators/elevators		
Vehicle interiors		

Question 5.16

How many cars make up the smallest independently operated vehicle that can be operated in your system? A married pair would be considered two cars for the purposes of this survey.

A. One
B. Two
C. Other (please describe)

Question 5.17

What is the configuration of the operating fleet used in typical daily operations?

A. Independently operated vehicles (including independently operated married pairs)
B. Entrained vehicles (including entrained married pairs)
C. Mixed (independently operated vehicles and entrained vehicles)
D. Other (please describe)

Question 5.18

What is the number of peak operating vehicles and trains required for an average operating weekday at your system?

A. Vehicles: ________________
B. Trains: ________________

Question 5.19

What is the total number of vehicles in your fleet?

A. Active vehicles in fleet: ________________
B. Inactive* vehicles in fleet: ________________
(*not usable for revenue service for reasons other than typical maintenance)
C. Total vehicles in fleet: ________________

Question 5.20

How is the coupling/uncoupling function managed at your system? Please provide additional information if these choices do not fully describe this function at your system.

A. Vehicle coupling and uncoupling are fully automated
B. Vehicle coupling is fully automated but uncoupling is performed manually
C. Vehicle uncoupling is fully automated but coupling is performed manually
D. Vehicle coupling and uncoupling are performed manually
E. Vehicle coupling and uncoupling are not performed

Question 5.21

What is the location of the vehicle maintenance facility at your system? If possible, please provide a drawing, plan, or map of the maintenance facility and yard area and its location in relation to your overall system.

A. Our vehicle maintenance facility is located online (i.e., at a station platform).
B. Our vehicle maintenance facility is located offline.
C. Other (please describe).

Question 5.22

How many hours per day is your system scheduled to operate? How many hours did your system operate in 2007? (If an on-demand system, how many hours per day is the system scheduled to be available for use?)

A. Scheduled average weekday operating hours: ________________
B. Scheduled average weekend day operating hours: ________________
C. Scheduled annual operating hours for 2007: ________________
D. Total hours actually operated in 2007: ________________

Question 5.23

How many on-guideway maintenance and recovery vehicles does your system have? How many incidents have occurred in your system where an in-service vehicle needed to be pushed/pulled by the MRV or another vehicle?

A. Number of MRVs: ______________
B. In-service vehicle push/pull incidents:
In 2007 In the Last 3 Years
______________ ______________

Question 5.24

What is your system's average weekday operating schedule? Please complete the following table and attach, upload, or send material as necessary to explain this answer.

ROUTE 1

Route Round Trip Time:							
Period	Begin	End	No. of Vehicles	No. of Trains	Hdway (sec)	System Config*	Mode**

ROUTE 2

Route Round Trip Time:							
Period	Begin	End	No. of Vehicles	No. of Trains	Hdway (sec)	System Config*	Mode**

ROUTE 3

Route Round Trip Time:							
Period	Begin	End	No. of Vehicles	No. of Trains	Hdway (sec)	System Config*	Mode**

*Pinched loop, shuttle, single loop, etc.
**Continuous, on demand, etc.

Question 5.25

What is the passenger capacity of a vehicle in your system? Please describe how this is determined (i.e., if it is obtained from the initial vehicle specification or technical proposal, through visual observation or passenger counts during peak periods, or by some other method). Please provide as much detail as possible about the capacity of your vehicles.

Question 5.26

Do passengers use luggage carts (e.g., Smarte Carte) on board your vehicles? If so, does the capacity number provided in Question 5.25 take this into account?

A. Do passengers use luggage carts (e.g., Smarte Carte) on board your vehicles? YES NO (if yes, please answer B and C)
B. Is the use of onboard luggage carts taken into account for the answer provided to Question 5.25? YES NO
C. How does the use of luggage carts on your vehicles affect your vehicle capacity? Please quantify this if possible.

Question 5.27

What is the capacity of your system?

	Scheduled Capacity During Peak Period*	Ultimate Capacity**
Route 1:	________________	________________
Route 2:	________________	________________
Route 3:	________________	________________
Route 4:	________________	________________

*Scheduled capacity during peak period can be calculated, for the purpose of this survey, as (No. of passengers that one vehicle can accommodate) × (No. of vehicles per train during the peak period) × (60/peak period directional headway in minutes).

**Ultimate capacity can be calculated, for the purpose of this survey, using the same formula, but under the following assumption: operating maximum-consist trains at the shortest headway without trains stopping outside stations, regardless of whether there are enough vehicles in the fleet to support such an operation.

Question 5.28

How is the system operation and operating schedule managed at your system?

A. The system is controlled based on a departure (trip) schedule, and our timetable is presented to the public as a headway schedule.
B. The system is controlled based on a headway schedule, and our timetable is presented to the public as a headway schedule.
C. Other (please describe)

Question 5.29

What is the total number of vehicle (fleet) miles accrued at your system in 2007?

A. In-service vehicle miles accrued in 2007: ________________
B. Other vehicle miles accrued in 2007: ________________
C. Total vehicle miles accrued in 2007: ________________
D. Average miles per vehicle accrued in 2007: ________________

Question 5.30

What is the total number of in-service vehicle (fleet) hours accrued at your system in 2007?

A. In-service vehicle hours accrued in 2007: ________________
B. Other vehicle hours accrued in 2007: ________________
C. Total vehicle hours accrued in 2007: ________________
D. Average hours per vehicle accrued in 2007: ________________

Question 5.31

What is the total number of passenger trips taken on your system in 2007? Please indicate how this number is obtained (e.g., through fare gate information, ticket sales, or other passenger counting systems, or if it is an estimate based on parking data, airline passenger data, or other external data).

Question 5.32

Are passengers charged a fare to use your system? If yes, please indicate the fare and basis.

A. YES
   Amount: ________________ per ________________
B. NO
C. Other (please describe)

Survey Section 6: Cost

Question 6.1

What are the costs to operate and maintain your system?

	FY 2007–2008 (budgeted USD)	FY 2006–2007 (USD)
Labor		
Management:	____________	____________
Administration:	____________	____________
Operations:	____________	____________
Maintenance—vehicles:	____________	____________
Maintenance—ATC/communication/power/track:	____________	____________
Maintenance—facilities/plant:	____________	____________
Materials:	____________	____________
Utilities		
Propulsion power:	____________	____________
All other:	____________	____________
Services/contracts		
Supplier technical support:	____________	____________
Security:	____________	____________
All other:	____________	____________
Profit and G&A:	____________	____________
Total:	____________	____________
Electrical cost per KWH:	____________	____________

Survey Section 7: Other

Question 7.1

Please provide any additional information about your system or airport APM performance measures that has not been covered by the previous survey questions and that you believe could be useful to our research.

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