4-1-2005

Reassessing Passenger Mile Data for Transit Planning and Fund Allocation

CUTR

Reassessing Passenger Mile Data for Transit Planning and Fund Allocation

Center for Urban Transportation Research
University of South Florida, Tampa

April 2005

BD549-06

National Center for Transit Research
Center for Urban Transportation Research
University of South Florida

1. Report No. NCTR-576-06, BD549-06	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Reassessing Passenger Mile Data for Transit Planning and Fund Allocation		5. Report Date April 2005 6. Performing Organization Code
7. Author(s) Xuehao Chu		8. Performing Organization Report No.
9. Performing Organization Name and Address National Center for Transit Research (NCTR) University of South Florida 4202 E Fowler Ave, CUT 100, Tampa, FL 33620-5375		10. Work Unit No. 11. Contract or Grant No. DTRS98-G-0032
12. Sponsoring Agency Name and Address Office of Research and Special Programs U.S. Department of Transportation, Washington, D.C. 20590 Florida Department of Transportation 605 Suwannee Street, MS 26, Tallahassee, FL 32399		13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

Supported by a grant from the Florida Department of Transportation (FDOT) and the U.S. Department of Transportation

16. Abstract

This document provides information on the collection and use of passenger mile (PM) data that may be helpful to the transit industry in reconsidering the use of PM data for transit planning and fund allocation. Historically the industry seldom uses PM data. This reluctance results largely from five perceptions that the industry has had about PM data: 1) determining PM is difficult; 2) determining PM is expensive; 3) PM data are unreliable; 4) using PM data in fund allocation favors transit agencies serving longer trips; and 5) PM data are not useful beyond reporting them to the National Transit Database. This paper provides evidence that determining PM is not as difficult or expensive as perceived and that PM data are more reliable than perceived. The paper also shows that using PM data in fund allocation can be neutral to transit agencies serving trips of different lengths. Finally, the paper presents examples of how PM has been usefully applied in the industry by both non-operating and operating agencies. By taking advantage of new data collection technologies and sampling methods, there are opportunities to productively apply PM data in transit planning and fund allocation.

17. Key Words Passenger miles, perceptions, reality, National Transit Database, transit planning, fund allocation	18. Distribution Statement Available to the public through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, 703-487-465, through the NCTR website at http://www.nctr.usf.edu, and through the FDOT website at http://www.dot.state.fl.us/transit/.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 23	22. Price

Reassessing Passenger Mile Data for Transit Planning and Fund Allocation

NCTR Principal Investigator:

Xuehao Chu
Center for Urban Transportation Research
University of South Florida
4202 East Fowler Avenue, CUT100
Tampa, Florida 33620
Phone: (813) 974-9831
Fax: (813) 974-5168
E-mail: xchu@cutr.usf.edu

NCTR Reviewers:

Patricia Ball
Victoria Perk
Steve Polzin
Joel Volinski

FDOT Project Manager:

Ike Ubaka
Public Transit Office
Florida Department of Transportation
605 Suwannee Street, MS 26
Tallahassee, Florida 32399
Tel.: 850-414-4500
Fax: (850) 414-4696
E-mail: Ike.Ubaka@dot.state.fl.us

Final
April 2005

DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the author(s) who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Florida Department of Transportation or the Research and Special Programs Administration. This report does not constitute a standard, specification, or regulation.

The report is prepared in cooperation with the State of Florida Department of Transportation and the U. S. Department of Transportation.

CONTENTS

INTRODUCTION 1
DETERMINING PM IS LESS DIFFICULT THAN PERCEIVED 3
Perception 3
Reality 4
Need for Sampling 4
Sample Size 6
New Technologies 7
Summary 7
DETERMINING PM IS LESS EXPENSIVE THAN PERCEIVED 7
Perception 7
Reality 8
FTA Proposal 8
User-Friendly Tools 9
PM DATA ARE MORE RELIABLE THAN PERCEIVED 9
Perception 9
Reality 10
USING PM DATA CAN BE NEUTRAL IN FUND ALLOCATION 10
Perception 10
Reality 11
Three Cases 11
Differential Effects for Individual Agencies 11
Group Comparison 13
PM DATA ARE USEFUL FOR TRANSIT PLANNING 14
Perception 14
Reality 15
Non-Operating Agencies 15
Operating Agencies 16
USING PM DATA HAS BENEFITED JTA 17
SUMMARY AND CONCLUSION 19
REFERENCES 21

INTRODUCTION

The transit industry in the United States uses two aggregate measures of service consumption for transit planning and fund allocation. The number of unlinked passenger trips (PT) measures the cumulative number of boardings by all passengers of a transit system. A passenger who boards three times to get from the origin to the destination, for example, consumes 3 PT. The number of passenger miles (PM), on the other hand, measures the cumulative distance traveled by all passengers. Eight PM, for example, could mean 8 passengers traveling 1 mile each or 1 passenger traveling 8 miles.

PT has certain theoretical advantages. At disaggregated levels, boarding volumes at individual stops are important to operations control and planning. At aggregated levels, it has been argued that the cost of providing transit services occurs at boarding (Fielding, 1987). It may also be argued that PT better reflects the fact that demand for transit services is a derived demand. People use transit services to meet their needs somewhere else. The needs of up to 8 people are met when 8 passengers traveling one mile each, while the need of only one person is met when 1 passenger traveling 8 miles.

While PT has certain merits as a measure of transit performance, the literature indicates that PM has advantages over PT as a measure of performance. Some view PM as a better measure of service consumption than PT for the following reasons:

- PM captures the essential function of mass transit—moving people across space (FTA, 2000; BTS, 2004). It can be argued that more service is consumed when 20 passengers travel 10 miles each than when 20 passengers travel one mile each.
- PM is a "less biased" measure of service consumption than PT (Taylor et al., 2002). PM, for example, avoids counting transfers as service consumption. When transfer rates range from 25 percent to 35 percent (Fielding, 1987), PT would overstate the number of linked trips by one-third to over one half.
- It is likely that most forms of transit user benefits, and even many non-user benefits, are proportional to PM (BTS, 2004).
- PM is comparable across modes (BTS, 2004). In contrast, 10 PT by fixed-route bus are not always comparable to 10 PT by demand responsive (Fielding, 1987).

Others view PM as a better link between service consumption and service provision:

- Longer trips require more transit service than shorter trips (FTA, 2000). Transporting passengers longer distances is likely to cost a transit agency more than transporting passengers shorter distances (GAO, 1979).
- Using PM is more effective in capturing service effectiveness than using PT (Thompson, 1999). Compare PM per vehicle mile with PT per vehicle mile for a 10-mile bus trip for two scenarios: 1) 20 people rode the full 10 miles; and 2) 20 people rode only one mile. The usage by these 20 people is reflected as 20 PM per vehicle mile under scenario 1 but only 1 PM per vehicle mile under scenario 2. In contrast, their usage is reflected as 2 PT per vehicle mile under both scenarios.

- PM better reflects the consumption of transit capacity (Fielding, 1987). Continue to use the two scenarios from adopted from Thompson (1999), assuming that the bus has a 20-seat capacity. While PT is 20 under both scenarios, the bus is full for the entire 10-mile trip under scenario 1, but empty for 9 miles of the bus trip under scenario 2.

Practical considerations, however, appear to be the driving force in how popular a particular measure of service consumption is for transit planning and fund allocation. During the late 1970s, federal transit funds were allocated on urban-based factors such as population and population density. In 1979, the General Accounting Office conducted a study of factors that should be included in a new funding allocation formula (GAO, 1979). While recognizing that service consumption may be a more important consideration than service supply, GAO did not include either PT or PM in its final recommendations to Congress. Several factors played a role in excluding service consumption. PT data were considered to be incomparable across transit agencies. More importantly, there were three perceptions related to data collection: 1) measuring PT and PM was considered to be difficult; 2) measuring PT and PM was considered to be highly costly; and 3) existing PT and PM data were believed to be unreliable.

A lot has changed in the popularity of PT data since then. PT data are now widely used for transit planning by both operating and non-operating agencies in the United States. Operating agencies use PT data for operations planning, for service planning, and for securing transit funds at the local level. Non-operating agencies use PT data for policy planning at various levels of government as well as for allocating transit formula grants at the state level. Over the years, the uniform reporting requirements of the National Transit Database have improved comparison of PT data across transit agencies. Furthermore, the increasing use of new technologies such as electronic fareboxes appears to have changed the transit industry's perceptions about the collection of PT data.

Little has changed in the popularity of PM data, however. The transit industry continues to be reluctant to use PM data for transit planning and fund allocation. One source of this reluctance is the same three perceptions in the late 1970s about the collection of PM data (FTA, 2000): 1) Determining PM is difficult; 2) Determining PM is expensive; 3) PM data are unreliable. The other source of this reluctance is two perceptions related to the use of PM data: 4) There is little or no use for PM data beyond reporting them to the National Transit Database; and 5) Using PM data in fund allocation favors transit agencies serving longer trips over agencies serving shorter trips.

Unlike the perceptions about both PT and PM data in the late 1970s, the current perceptions about PM data are misperceptions and do not fully reflect the reality. Following this introduction, the paper is organized into seven sections. The first five of these sections address the misperceptions about PM. Specifically, each section first describes a misperception and discusses how this misperception may have undermined the industry's interest in using PM and then examines how this misperception deviates from reality. The reality is explored in terms of current practices and what they are likely to be in the near future when new technologies are deployed more widely and deeply in the industry. After examining these misperceptions, the paper illustrates the potential benefits of using PM data in transit planning with a case study of a particular transit agency in Florida. The last section summarizes the findings of the study and concludes that it is time for the industry to reconsider using PM data for transit planning and fund allocation.

DETERMINING PM IS LESS DIFFICULT THAN PERCEIVED

Perception

Two factors may have contributed to the perception that it is difficult to determine PM. First, more information needs to be collected for determining PM than for determining PT. Consider a single one-way bus trip. To determine PT would require one to keep track of the number of people who board the bus along the route, but not where these people board the bus. Nor does one need to know where these people alight. To determine PM, on the other hand, requires one to keep track of the number of passengers on board between every two consecutive stops and the distance between the two stops. One way to obtain the number of passengers on board between every two consecutive stops would be to keep track of not only the number of people who board at each stop but also the number of people who alight at each stop.

Second, sampling is far more widely used for determining PM than for determining PT for the NTD. Recipients and beneficiaries of the Urbanized Area Formula Program grants (Section 5307 Program) must report ridership data (both PT and PM) to the NTD through the life of the grant and/or capital equipment obtained through the grant. Agencies may use either a 100-percent count or an estimate from a random sampling procedure for annual PT and PM data reported to the NTD (FTA, 2004).

When a sampling procedure is used, a transit agency may use any random sampling procedure that meets the minimum confidence level of 95 percent and the minimum precision level of ±10 percent. One widely used option is the FTA-approved sampling plans for fixed-route bus services (UMTA, 1988). Alternative techniques may be used but need to be certified by qualified statisticians.

For the given confidence and precision levels, any sampling technique is based on mainly two factors: a specific parameter and its statistical variation across sampling units. The most relevant parameters are PT, PM, average passenger trip length in miles (TL), and farebox revenues. Depending on the sampling parameter used, sampling plans may be referred to as PM-based if they are based on the statistical variation in PM, PT-based if they are based on the statistical variation in PT, TL-based if they are based on the statistical variation in TL, etc. The FTA-approved sampling plans are PM-based.

Approximately 150 transit agencies in the United States were contacted via phone about the specific techniques they used to collect field data on PT and PM for reporting to the NTD in 2002. These are the full set of agencies that reported complete PT data for 2001 to both the American Public Transportation Association as a member and to the NTD.

Information on data collection techniques is available for 122 of these agencies (Table 1). A total of 42 agencies (34 percent) determined PT through random sampling, compared to all 122 agencies (100 percent) determining PM through sampling. Thus, it appears that the perceived level of effort involved in determining PM through sampling would tend to discourage its use.

Table 1. Comparing Techniques for Collecting Field Data for PM and PT

<table>
<tr><th colspan="2" rowspan="3">Technique for Collecting Field Data for PM</th><th colspan="5">Technique for Collecting Field Data for PT</th></tr>
<tr><th rowspan="2">Counting</th><th colspan="3">Sampling</th><th rowspan="2">Total</th></tr>
<tr><th>FTA-approved</th><th>Alternative</th><th>Total</th></tr>
<tr><td colspan="2">Counting</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td rowspan="3">Sampling</td><td>FTA-approved</td><td>43</td><td>16</td><td>2</td><td>18</td><td>61</td></tr>
<tr><td>Alternative</td><td>27</td><td>0</td><td>24</td><td>24</td><td>51</td></tr>
<tr><td>Total</td><td>70</td><td>16</td><td>26</td><td>42</td><td>122</td></tr>
<tr><td colspan="2">Total</td><td>70</td><td>16</td><td>26</td><td>42</td><td>122</td></tr>
</table>

Reality

The reality of the level of difficulty in determining PM is examined from three aspects. The first two relate to sampling as the source of the perceived difficulty in determining PM. The real level of difficulty due to sampling depends on both the need for sampling and the minimum sample size. The third aspect relates to the perception that determining PM is difficult because more information needs to be collected for determining PM than for determining PT. The real level of difficulty due to the requirement of more information depends on the tool used. The state of the art technologies level the playing field between PM and PT.

Need for Sampling

The need for sampling is addressed from two perspectives. The first perspective focuses on whether transit agencies still need sampling even when PM data were no longer required to be collected. The second perspective deals with how new technologies can save transit agencies from determining PM through sampling.

<u>No PM Data</u>. If collecting and reporting PM were no longer required, sampling would not be needed for transit agencies that determine PT directly through counting every boarding. Among the 122 agencies in Table 1, 70 (57%) count every boarding. Other agencies, however, would still need sampling to estimate PT. The change in sample size for these agencies depends on the sampling technique they use before and after the hypothetical change in the requirement of PM reporting.

Consider two cases. The FTA-approved sampling plans are used in the before scenario in one case, while PM-based sampling plans that are customized to an agency's conditions are used in the before scenario in the other case. In both cases, PT-based sampling plans that are customized to an agency's conditions are used in the after scenario. Table 2 shows three sets of customized sampling plans for four particular agencies. These sampling plans follow the same framework as the FTA-approved plans but are customized to the specific conditions of these agencies' fixed-route bus services. These plans are designed using the guidance developed by Chu and Ubaka (2004). The FTA-approved sampling plans are shown in the bottom row.

Table 2. Daily Sample Size by Sampling Frequency and Parameter, FY 2002

Agency	*Sampling Parameter*	*Sampling Plan/Frequency*					
		1	*2*	*3*	*4*	*5*	*6*
		Every Day	*Every 2nd Day*	*Every 3rd Day*	*Every 4th Day*	*Every 5th Day*	*Every 6th Day*
OCTA	PT	1	2	3	5	8	17
	PM	1	2	4	7	17	N/A
	TL	1	1	1	2	2	3
Riverside	PT	1	2	3	5	12	N/A
	PM	1	4	12	N/A	N/A	N/A
	TL	1	2	2	4	7	19
PSTA	PT	1	2	3	5	10	26
	PM	1	3	6	16	N/A	N/A
	TL	1	1	1	1	2	2
HARTline	PT	1	2	3	5	9	23
	PM	1	3	6	20	N/A	N/A
	TL	1	1	2	2	3	5
FTA	PM	2	3	5	7	10	15

Note: "N/A" indicates that the particular sampling frequency will not yield the FTA's minimum confidence and precision levels regardless how many trips are sampled. The sample sizes are in one-way bus trips.

For the first case, the objective is to compare the daily sample sizes between the FTA-approved sampling plans and the customized PT-based plans for each sampling frequency. The sample size in the PT-based plans is smaller with the exception when the sampling frequency is the lowest at every 6th day, which is rarely used. The objective in the second case, on the other hand, is to compare the daily sample sizes between the PT and PM rows for each given agency. Except sampling every day, the PT-based sampling size is smaller as expected because PM varies more than PT across one-way bus trips. The wider differences with lower sampling frequencies result from the fact that sample size is more sensitive to the statistical variation in the sampling parameter at lower frequencies.

<u>New Technologies</u>. Boyle (1998) reviews passenger counting technologies. Just as electronic registering fareboxes have saved many transit agencies from determining PT through sampling, new technologies also can save them from determining PM through sampling. For paratransit operators, automated dispatch systems that track the revenue mileage for all passenger trips allow agencies to count every mile their passengers travel (FTA, 2000). For rail services, faregate-controlled systems that record entry and exit

station of each passenger also allow a direct and full count (FTA, 2000). When used by all passengers, smart cards also are promising technologies if they can keep track of three pieces of information: 1) where every individual passenger boards and alights; 2) what path every individual passenger takes; and 3) what is the distance between the origin and destination through the traveled path.

For fixed-route bus services, the most promising technology in the short to middle term is automatic passenger counters (APCs) installed in the entire fleet (Furth, 2000). A recent survey indicates that 11 transit agencies in the United States already had APCs on their entire fleet of fixed-route buses (FTA, 2003). The number of such agencies is expected to continue to grow based on the recent growth in the number of transit agencies adopting APC technologies and in the total number of APCs installed. In fact, the number of agencies with operational APCs increased from 24 in 1998 to 60 in 2002, and is expected to increase to 184 in 2005 (FTA, 1999, 2003). Over the period from 1995 to 2002, the number of agencies adopting APCs grew almost 500 percent (FTA, 2003).

Sample Size

The perception of determining PM being difficult results partially from using an inappropriate minimum sample size to achieve desired confidence and precision levels. This is true for the following two cases: 1) both PT and PM are determined through sampling; and 2) only PM is determined through sampling.

<u>Sampling for PT and PM</u>. When both PT and PM are determined through sampling, sampling should be PM-based, i.e., based on the statistical variation in PM, because PM varies more than PT across sampling units, such as one-way bus trips. Among the 42 agencies in Table 1 that sample for determining both PT and PM, 16 use FTA-approved sampling plans for PT and 18 for PM. Chu (2004b), however, has shown that these FTA-approved sampling plans do not necessarily yield FTA's own confidence and precision levels for individual agencies. The more appropriate sample sizes to examine would be for sampling techniques that are PM-based and are customized to the specific conditions of individual agencies.

The PM rows in Table 2 show these customized plans for four transit agencies. For sampling every day, the customized sample size is half of the FTA sample size for all four agencies. For sampling at lower frequencies, on the other hand, the relative sample sizes between customized and FTA-approved sampling plans vary across agencies and plans. In any case, greater customized sample size indicates that using FTA-approved plans would violate FTA's confidence and precision levels, while smaller customized sample size indicates that using FTA-approved sampling plans mean over-sampling.

<u>Sampling for PM</u>. When only PM is determined through sampling, sampling should be based on the statistical variation of TL. Among the 70 agencies in Table 1 that directly count PT, 43 (61%) use FTA-approved sampling plans. Using FTA-approved sampling plans in this case is likely to lead to significant over-sampling for many agencies because the statistical variation in PM in general is significantly greater than that in TL. The

FTA-approved sampling plans again cannot be used for comparing the sample sizes corresponding to PM-based and TL-based sampling. Rather, an appropriate comparison would be PM-based and TL-based sampling plans that are customized to the specific conditions of individual agencies. The TL row in Table 2 shows the customized TL-based sample sizes. It is clear that the difficulty concern is seriously over-rated in this case because using TL-based sampling would dramatically reduce the minimum sample size requirement when sampling less frequently than every day in order to determine PM. PSTA, for example, would need to sample 16 one-way bus trips using PM-based sampling, but only 1 one-way bus trip using TL-based sampling.

New Technologies

New technologies not only can save agencies from sampling for determining PM, as discussed earlier, but also level the playing field between determining PM and determining PT through sampling. As already discussed, more information does need to be collected to determine PM than PT at any level of aggregation (vehicle trips, routes, service, agency, etc.). It is also true that the collection of this extra information would make determining PM more difficult than determining PT when the collection is manual. However, the collection of the extra information does not make determining PM more difficult when the collection process is largely automated through the use of new technologies.

Summary

Transit agencies that currently determine both PM and PT through sampling would still need to sample even if PM data were no longer required for the NTD. These transit agencies can do better when PM data are still required by using customized sampling plans rather than FTA-approved sampling plans. On the other hand, transit agencies that currently determine only PM through sampling would not need to sample if PM data were no longer required for the NTD. However, many of these agencies currently still use FTA-approved sampling plans for determining PM and unnecessarily over-sample in many cases. For all agencies, new technologies will even the levels of difficulty between determining PM and determining PT even though more information needs to be collected for determining PM.

DETERMINING PM IS LESS EXPENSIVE THAN PERCEIVED

Perception

At least two factors may have contributed to the perception that determining PM is expensive to transit agencies (FTA, 2000). The first factor relates to the absolute cost involved in determining PM. When used, sampling may require as much as the effort of one person-year for each mode of service (FTA, 2000). At many agencies, there is also the need for hiring statisticians to develop a sampling plan and to process the sampling data into an estimate of PM.

The second factor relates to how much funding an agency gets from a grant program relative to the cost of determining PM for the program. While ridership is a factor in allocating transit grants at the federal and state levels, the Urbanized Area Formula Program is the only one known to use PM (Chu, 2004a). The PM data are used in the "Incentive Tier" of the program only for transit agencies in urbanized areas with a population of 200,000 or more. Many agencies eligible for the bus incentive tier have indicated that the cost for determining the PM data exceeds the funding they receive as a result of reporting it (FTA, 2000). For agencies in smaller urbanized areas, there is no direct funding return on the cost associated with collecting the PM data.

Reality

The reality on the cost for determining PM is largely reflected by the reality on the level of difficulty in determining PM. In addition, however, the cost for determining PM may be reduced by lowering the required sampling frequency in the NTD, as proposed by FTA (2000). Furthermore, the cost for determining PM can be reduced by making user-friendly tools available for transit agencies to develop alternative sampling techniques that improve sampling efficiency or reduce administrative costs of sampling without the need for hiring outside statisticians.

FTA Proposal

FTA (2000) proposes to reduce the frequency of mandatory sampling for agencies that currently are required to sample every year and report a 100-percent PT count. Specifically, these agencies would be required to sample only when there is a relatively large service change, such as more than 10 percent. These agencies would simply multiply the 100-percent PT count for the current year with the average TL from last year to determine PM. The hypothesis is that changes in average TL across years are likely to be small when service changes are small. That is, year-to-year changes in average TL are positively and highly correlated with year-to-year changes in services provided.

To test this hypothesis, the degree and direction of correlation between year-to-year changes in average TL and year-to-year changes in provided services are estimated. Changes in service can be in different forms such as changes in frequency, new routes, or route extensions. These changes may influence average TL quite differently. Without these service components separately measured, however, one has to rely on the aggregate service measures in the NTD, including vehicle revenue miles and vehicle revenue hours. The data are from the NTD for the years from 1992 to 2001, including all 73 transit agencies in the NTD for which average TL can be calculated for each year during this period. Both vehicle revenue miles and revenue hours are considered. The correlation is examined in two different ways: year-to-year absolute changes and year-to-year percent changes for both services and average TL. The results show that the correlation coefficient is less than 0.06 in absolute values for all four cases defined by the two measures of percent changes and the two measures of services provided. That is, the evidence does not support the hypothesis that year-to-year changes in average TL are correlated with year-to-year changes in services provided.

User-Friendly Tools

The literature has many alternative sampling techniques, which have two cost-saving objectives in general. One is to improve sampling efficiency over the FTA-approved sampling plans, i.e., reducing sample size for the same confidence and precision levels. The other is to reduce the administrative costs of sampling. Two commonly used techniques to improve sampling efficiency are sample stratification (Smith, 1983) and ratio estimates (Furth and McCollom, 1987). One common technique to reduce administrative costs is cluster sampling (Furth et al., 1988). The presentation of these alternative techniques is too technical for most transit agencies to apply directly. The FTA can do a better job of providing user-friendly tools for transit agencies to develop alternative sampling techniques on their own. These tools not only can potentially improve sampling efficiency and reduce administrative costs, but also can save agencies the cost of hiring outside statisticians.

Chu and Ubaka (2004) have made a first step toward that end by developing a guide and Excel-based templates for transit agencies to customize sampling plans to the conditions of their own fixed-route bus services. The guide provides direction to transit agencies that have or expect to have the 100-percent PT count for determining sampling plans. Guidance is also provided for agencies that do not have a 100-percent PT count. This guide complements "Sampling Procedures for Obtaining Fixed Route Bus Operating Data under the Section 15 Reporting System," FTA Circular C2710.1A. Essentially, a transit agency would (1) replace the table of sampling plans in Table II-1 in the Circular with those it develops using the guide, (2) select of one of the customized plans that best meet its staffing needs, and (3) follow the procedures in the Circular on sampling and collecting field data.

Table 2 shows the sample plans developed using this guide for four agencies under FY2002 conditions. If an agency with these conditions does not have the 100-percent PT count or chooses not to use the count to determine its PM, it can cut the sample size by 50 percent if it chooses to sample every day (FTA versus PM rows). At the same time, it will not meet FTA's required accuracy if it samples less frequently than every 2nd day. Otherwise, it can significantly reduce the sample size for any frequency of sampling (FTA versus TL rows). Riverside is the only exception among these four agencies at the lowest sampling frequencies. On the other hand, PSTA needs only to sample 1 instead of 7 one-way bus trips if it samples every 4th day.

PM DATA ARE MORE RELIABLE THAN PERCEIVED

Perception

PM data are often considered to be unreliable. Taylor et al. (2002) consider PM to be "more telling and less biased" measures of transit ridership, but consider available PM data to be unreliable. FTA (2000) considers the measurement of PM to be an error-prone process with the resulting PM data containing frequent non-sampling errors. Thompson (1999) believes that determining PM through sampling leaves a lot of room for error.

Reality

The reality on the level of reliability of PM data is also partially reflected by the reality on the level of difficulty in determining PM. This section explores the reality from two other perspectives. The first is the potential reliability achievable by transit agencies that directly count PM using new technologies such as APCs. Assuming no adjustments through sampling, a full count of PM involves no sampling errors just like a full PT count does. Given the large growth rates mentioned earlier in the number of agencies adopting APCs and in the number of APCs installed, it is reasonable to expect that the number of agencies that determine PM through direct counting would also grow at a fast rate.

The second perspective is in terms of the actual confidence and precision levels achieved by transit agencies that report 100-percent PT counts but still use FTA-approved sampling plans to estimate average TL. Among the 70 agencies in Table 1 that report 100-percent PT counts to the NTD, over 60 percent use FTA sampling plans to estimate TL. Using FY2002 data for the four agencies in Table 2, the confidence and precision levels in estimated average TL that would be achieved by these agencies if they use FTA-approved sampling plans are calculated. Given the confidence level of 95 percent, the precision level ranges from ±4 percent for OCTA to ±7 percent for Riverside, compared with the maximum ±10 percent required by the NTD. Given the precision level of ±10 percent, on the other hand, the confidence level is greater than 99 percent for all four agencies, which is much higher than the minimum 95 percent required by the NTD. Therefore, PM data as collected are more reliable than perceived.

USING PM DATA CAN BE NEUTRAL IN FUND ALLOCATION

Perception

Ridership is used in allocating transit formula grants at the federal level and in at least five states: Florida, Indiana, Iowa, New York, and Ohio (Chu, 2004a). In FY 2003, the federal program allocated about $3.5 billion to transit agencies in urbanized areas (Chu, 2004a), while the funds allocated by the transit formula grant programs in the five states total around $200 million per year (Chu, 2004a). Ridership appears as PT or PM in transit formula grant programs. While the state programs all use PT, the federal program uses PM in the “Incentive Tier” for both fixed-guideway and bus services. The bus incentive tier represents less than 6 percent of the federal program and is apportioned on the basis of PM weighted by PM per unit of operating cost.

It is perceived that using PM data in allocating transit formula grants rewards agencies serving longer passenger trips in miles but punishes agencies serving shorter passenger trips. One would expect that agencies serving suburbs are more likely to serve relatively longer passenger trips than agencies serving central cities. To the degree that this expectation is true, using PM data in fund allocation increases the equity concern that transit funding in the United States already favors suburbs over central cities (Garrett and Taylor, 1999).

Reality

It is true that using PM as the only measure of rideship for fund allocation does favor agencies serving longer trips. It is also true that using PT as the only measure of ridership for fund allocation favors agencies serving short trips. The full reality is that whether and the degree to which using PM data in fund allocation favors one group over another depends on how PM data are used in the allocation formula. This reality is illustrated in three steps in the context of the bus incentive tier of the Urbanized Area Formula Program. The first step presents three alternative formulas for allocating the bus incentive tier. The second step examines analytically how these alternative formulas would affect the apportionment to individual agencies. The third step empirically compares the apportionment across groups of transit agencies based on the average TL for each agency.

Three Cases

Consider three cases of how PM may be used in a formula of allocating transit grants:

- PM*PM: This is how PM data are currently used for apportioning the bus incentive tier of the Urbanized Area Formula Program. As already mentioned, the bus incentive tier is apportioned on the basis of PM weighted by PM per unit of operating cost. This is one extreme where only PM is used to represent ridership.
- PT*PT: One alternative case is to apportion the bus incentive tier on the basis of PT weighted by PT per unit of operating cost. This is the other extreme where only PT is used to represent ridership.
- PM*PT: The other alternative case is to apportion the bus incentive tier on the basis of PM weighted by PT per unit of operating cost. This is a balanced case between the above two extremes cases. Both PT and PM are used and used symmetrically.

Differential Effects for Individual Agencies

Given that PM equals the product of PT (T_i) and average TL in miles (L_i) for any system, the resulting allocation of total funding A for the bus incentive tier to agency i can be determined with the following formula:

$$A_i^n = A \frac{T_i^2 \, L_i^n / O_i}{\sum_j T_j^2 \, L_j^n / O_j}$$

where O_i is the amount of operating expenses, and n = 2, 1, or 0, representing the PM*PM case, the PM*PT case, and the PT*PT case, respectively. Note that n plays a different role for the apportionment to agency i than for the average TL for agency i. For average TL, *n* represents the power, while it represents a superscript for one of the three cases. It is clear that the role of average TL distinguishes these three cases.

A fundamental question is: Under what conditions would one agency do better with one case over another? It turns out that these conditions have to do with how the average TL of an agency compares with three critical values, which represent three weighted national average passenger trip lengths across all agencies: L_{10}, L_{20}, and L_{21}. The following equations compute these critical values:

$$L_{10} = \frac{\sum_j T_j^2 L_j / O_j}{\sum_j T_j^2 / O_j},\ L_{20} = \sqrt{\frac{\sum_j T_j^2 L_j^2 / O_j}{\sum_j T_j^2 / O_j}},\ L_{21} = \frac{\sum_j T_j^2 L_j^2 / O_j}{\sum_j T_j^2 L_j / O_j}$$

Each of these critical values differs from the commonly defined national average passenger trip length, L:

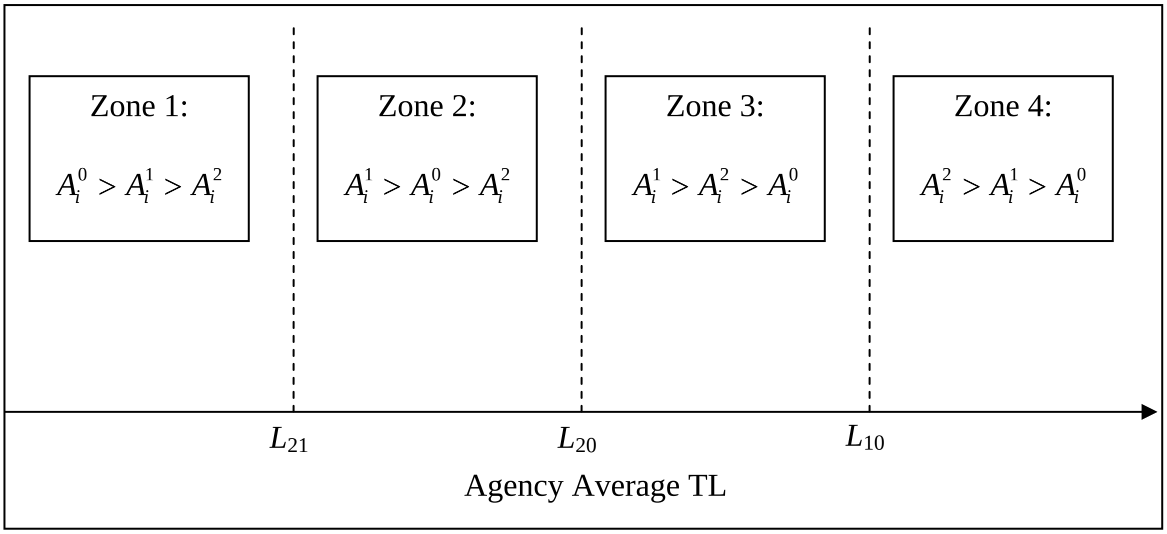
$$L = \frac{\sum_j T_j L_j}{\sum_j T_j}$$

These critical values have clear interpretations. For example, an agency would be apportioned the same amount with $n = 2$ or $n = 1$ if its average TL equals L_{21}. The other two have similar interpretations.

Figure 1 shows how the apportionment to an agency depends on how its average TL compares with the three critical values defined above. The horizontal axis measures agency average TL in miles. Trip lengths increase from left to right, with each successive zone reflecting longer trips than the zone before. The three critical values divide the horizontal axis into four zones. For each zone, the figure shows how the three cases compare in terms of their apportionments to individual agencies whose average TL happens to be in this zone.

Consider several scenarios. Under scenario one, the average TL of an agency is shorter than L_{21}. The agency would get the most apportionment with the PT*PT case, and would get the least with the PM*PM case. Under scenario two, the agency TL is greater than L_{10}. The agency would get the most apportionment with the PM*PM case. Under both scenarios, the apportionment from the PM*PT case lies in the middle of the apportionments from the two extreme cases. Under scenario three, the agency TL is in the middle range between L_{21} and L_{10}. The agency would get the most apportionment under the PM*PT case, and the least with the PT*PT case. The relative apportionments resulting from the other two cases depend on whether the agency TL is shorter or longer than L_{20}. If the agency TL is shorter, it would do better with the PT*PT case. Otherwise, it would do better with the PM*PM case.

Figure 1. Effects of Agency Average TL on Agency Apportionment



This analysis confirms the perception that using PM alone in fund allocation favors transit agencies serving longer trips. It also confirms that using PT alone favors transit agencies serving shorter trips. More important, this analysis shows that using both PM and PT in a symmetrical way neutralizes the biases resulting from using either PM or PT alone in fund allocation.

Group Comparison

NTD data for 2003 are used to compare the apportionment of the bus incentive tier to agency groups defined by the four zones in Figure 1. Only motorbus is considered. There are 445 reporting agencies that have complete data on PT, PM, and operating expenses. For these agencies, the three critical values are: L_{10} = 3.24 miles, L_{20} = 3.84 miles, and L_{21} = 4.56 miles. For comparison, L = 3.68 miles. The number of agencies is 130, 79, 67, and 169 in zones 1 through 4, respectively. That is, there are 169 agencies in 2003 whose average TL for their fixed-route bus services is greater than 4.56 miles.

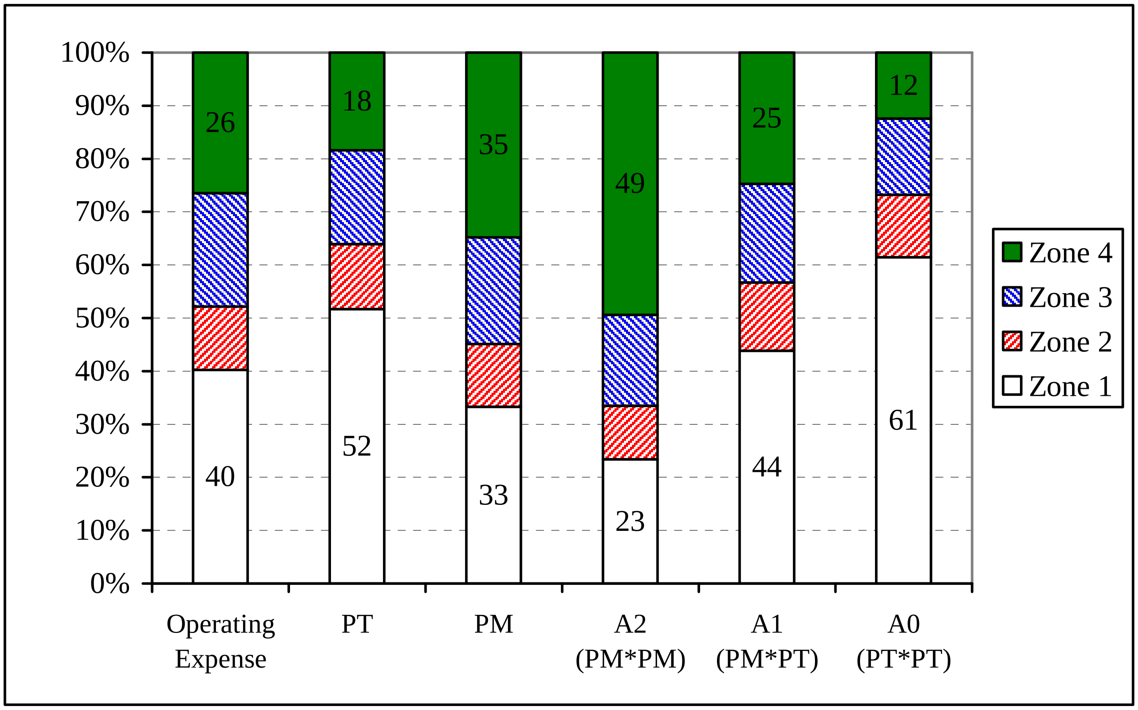
Figure 2 shows the apportionment under each case, A_2, A_1, and A_0, as well as the distribution of service consumption (both PM and PT) and operating expenses. It is interesting to note that Zone 1 represents over one half of all PT consumed, but that PM is almost evenly distributed among Zone 1, Zone 4, and Zones 2 and 3 combined. Another interesting difference across the four zones is that the average operating cost per PT increases systematically with longer average TL. In fact, the average operating cost per PT is $2.06 for Zone 1, $2.58 for Zone 2, $3.20 for Zone 3, and $3.81 for Zone 4.

The apportionment to Zones 2 and 3 combined is relatively stable across the three alternative cases of using PM data in fund allocation. The apportionments to Zone 1 and Zone 4, however, vary dramatically. The apportionment to Zone 1, i.e., agencies with the shortest average TL, varies from 23 percent with the PM*PM case to 61 percent with the

PT*PT case. The apportionment to Zone 4, i.e., agencies with the longest TL, varies from 49 percent with the PM*PM case to 12 percent with the PT*PT case.

These dramatic variations in apportionments to Zone 1 and Zone 4 illustrates that either using PM only or using PT only in fund allocation favors one group over another. Unlike these two extreme cases, however, the apportionment with the case where both PM and PT are used represents a balance between these two extreme cases. Furthermore, this balanced apportionment reflects the distribution of operating expenses well.

Figure 2. Alternative Percent Apportionments to Agency Groups



PM DATA ARE USEFUL FOR TRANSIT PLANNING

Perception

PM data as reported to the NTD are considered to be of limited usefulness (FTA, 2000). One factor is the perceived non-sampling errors in the PM data from the process of determining PM through sampling. Another factor is that FTA's minimum confidence and precision levels are designed for the system level. Service planning, however, requires data to be statistically reliable at least at the route level rather than the system level. Thirdly, it is perceived to be difficult to use PM in ways that have broad applicability.

Reality

The reality is that PM data are already widely used by non-operating agencies for transit planning and fund allocation. Some operating agencies have also been using PM data for a variety of applications. The full potential of PM data for operating agencies can only be realized with the deployment of new technologies that allow automated collection of a large amount of data at relatively low costs.

Non-Operating Agencies

Federal Level. USDOT (2003) now uses yearly growth rates in PM as the performance measure on transit ridership at the national level, and uses PM as a measure of exposure to injury risk for transit users. In addition to the Urbanized Area Formula Program, PM is used in the Clean Fuels Formula Grant Program, which is designed to accelerate the deployment of advanced bus technologies (FTA, 2002a). One half of the funds are allocated based on the number of vehicles in the bus fleet and the other half on the number of bus PM as weighted by severity of non-attainment for either ozone or carbon monoxide. Finally, USDOT's *Conditions and Performance Report to Congress* uses projected PM to estimate transit investment needs nationwide (FHWA, 2003). The transit investment analysis is based on the Transit Economic Requirements Model (TERM). The projected growth rate in PM is one of the most important parameters in the TERM, particularly for the Asset Expansion Module, which programs the purchase of transit vehicles and other assets required to maintain the base year level of performance (based on vehicle utilization rates).

State Level. The ratio of PM to seat miles available or load factor is used as a performance measure for transit capacity utilization in FDOT's Mobility Performance Measures Program (FDOT, 2000). Capacity utilization indicates whether or not a transportation system is properly sized and has the ability to accommodate growth.

Following the development of the *2020 Florida Transportation Plan* (FTP), FDOT wanted new ways of measuring the performance of its transportation system over time relative to the goals and objectives in the 2020 FTP. The Program is based on a set of principles: 1) the process is policy-driven and is supported by data; 2) the measures reflect users' experience on the system; 3) the measures address multimodal considerations; 4) the results are understandable to the general public; and 5) the results from the performance measures can be forecast into the future.

In 2002, the Washington State Transportation Commission, on the recommendation of the Washington State Transit Association, adopted the following transit performance benchmarks: operating cost per total hour as cost efficiency; cost per PT and cost per PM as cost effectiveness; and PT per revenue hour as service effectiveness (Bremmer, 2002; WDOT, 2005). Two measures are used for cost effectiveness because PT varies greatly in distance, and cost per PM adjusts for differing trip lengths, making the measure more appropriate for comparisons between systems.

Local Level. Fulton County, Georgia, uses PM as a performance measure for transit services in its current *Comprehensive Transportation Plan* (Fulton County, 2000) for the objective of improving transit accessibility, service, and options. Metroplan Orlando (2002) uses PM per dwelling as a performance measure in its *2025 Long Range Transportation System Plan*. Cleveland proposed to use PM as a long-term measure of transit performance but to use customer satisfaction as a short-term measure.

In its *2004-2008 Transit Development Program*, Ohio's Eastgate Regional Council of Governments (2003) uses PM per vehicle mile in defining a route service standard. The standard is at least 50 percent of the average across all routes. Routes are considered deficient in PM per vehicle mile if they do not meet this standard.

The North Jersey Transportation Planning Authority (2002) has a set of 19 performance measures for its Congestion Management System (CMS). These performance measures fall into eight performance goals: accessibility, reliability, sustainability, intermodality, highway mobility, transit mobility, walk and bike mobility, and freight mobility. The performance goal of transit mobility has transit time, one-seat ride, and crowding as component performance measures. The transit time component measures the ratio of employment reached within 60 minutes using congested transit time divided by employment reached within 40 minutes using congested highway time. The one-seat ride component measures the number of households having a one-seat ride to six key employment centers by express service. The transit crowding component measures PM at critical locations over capacity.

The MPO of the San Diego region (SANDAG, 2004) has had a passenger counting program for 20 years. On behalf of the region's seven transit operators, it collects data from all trips operated along each fixed-route transit route during one weekday once per year. The data are made available online through a set of standardized reports at the stop, direction, period, trip, and/or route level. The Transit Passenger Counting Program, Version 3.0, allows 14 different reports. These reports summarize data on boardings, alightings, passenger miles, maximum load, and schedule adherence at disaggregated levels and services provided and consumed at more aggregated levels. One data item at the more aggregate level is load factor calculated as the ratio of PM to seat miles.

Operating Agencies

PM data can be useful for operating agencies when reliable data are available at the system level as well as at more disaggregated levels. Consider two examples at the system level beyond the typical performance measures. First, in applying for grants through the Section 5309 New Starts Program, applicants are required to show absolute changes in operating cost per PM for the entire regional transit system between the baseline and forecast years as the only measure of operational efficiency (FTA, 2002b). The FTA also requires that this measure be reported by mode if applicable and available. Second, through reviewing contemporary risk management practices for six transit agencies in the United States, Chaney and Derr (1996) find that the casualty and liability risk is significantly lower for the larger agencies than the smaller agencies. They conclude that PM is the most appropriate measure of exposure to measure the risks to casualty and liability costs that individual agencies face.

Transit agencies routinely need to re-allocate resources across their temporal and spatial markets based on productivity evaluations of these markets. These markets are typically spatial at the route level, but often are temporal as well by time of day and day of week. It is feasible to collect the necessary data manually at these disaggregated levels through non-random sampling. To be truly cost-effective for operating agencies, however, disaggregated data need to be routinely and automatically collected with new technologies through a random sampling process. Many agencies are already doing that, including the Central Ohio Transit Authority (Barry, 1993), Jacksonville Transit Authority (Florida) (see the case study in the next section), and Tri-Met (Oregon) (Furth et al, 2003). While new technologies do require initial investments, they benefit transit agencies in many ways over time. When applied appropriately, they offer more reliable data than manual data collection methods. They allow more frequent service evaluation and service changes when needed. They allow the generation of many new performance measures beyond traditional route productivity measures for service evaluation. In fact, a body of literature now exists that attempts to generate transit performance measures at various levels of aggregation from archived electronic data collected with new technologies (Bertini and El-Geneidy, 2003; Furth et al., 2003). Examples include the percent of PM under crowded conditions, the percent of PM at a certain level of service reliability, etc.

USING PM DATA HAS BENEFITED JTA

The collection and use of PM data at the Jacksonville Transportation Authority (JTA) are described to illustrate potential benefits of using PM data for transit planning by operating agencies. JTA serves Duval County, Florida, with a system of 71 fixed-route bus routes, a trolley, and a people mover. The service area is divided into four quadrants: Southside, Arlington (eastside), Westside, and Northside. JTA previously monitored the performance of its bus system in terms of PT, which declined in the early 1990s. Like most bus systems, JTA was plagued with the perception that it moved air (empty buses) rather than passengers. Then it decided to “declare a war” on air and developed a five-element strategy to win the war (Figure 3). The following description of this strategy is based on JTA (2004a, 2004b) and CUTR (2002).

- *Use PM to Measure Riderhsip*. JTA believes that PT alone does not reveal the entire picture of the usage of its bus system because a bus trip could have a high volume of short PT but it is empty for a majority of the trip, and that PM accurately portrays actual usage of the bus system. As a result, JTA switched from using PT to using PM to track utilization of its fixed-route bus system. It also switched from using PT-based productivity measures to PM-based measures at the system level: PM per revenue mile and PM per revenue hour.

- *Use APCs to Collect Data*. JTA leased 3 units in December 1994 from Urban Transportation Associates to demonstrate the capabilities of APCs. Following the satisfactory demonstration, JTA purchased 7 units in early 1996, 13 units in May 1998, and an additional 10 units in December 1999. By late 2003, 25 buses were equipped with APCs. In addition to other information, the APCs provide data for JTA to estimate average TL for each route, which is then used in combination with route-level PT from electronic registering fareboxes to estimate route-level PM.

- *Use Load Factor to Measure Route Productivity*. To win the war on air, JTA needs to know how empty the buses are. JTA believes that the best measure to help it determine that is load factor, which measures how full a bus is over the duration of an entire bus trip. It is calculated by dividing route-level PM by route-level seat miles. A load factor of 1.0 on a route means that all of the available seats are occupied by passengers during the entire length of every bus trip. On a radial route with peaked directional traffic, on the other hand, a load factor of 0.5 would mean that all seats are largely occupied in the primary travel direction. A low load factor on a route, JTA believes, means that there is too much service being provided on this route, and that either the frequency can be cut back, or a change in the route design can be made to increase usage.

  JTA groups all bus routes into four performance categories using a PM-based measure of load factor. A route is a top performer if its load factor is 20 percent or higher, a promotion target if its load factor ranges from 15 percent to 19 percent, a re-design target if its load factor ranges from 10 percent to 14 percent, and a poor performer if its load factor is below 10 percent. Different actions follow for different categories:

  - Top Performers: No immediate action is required. These lines should be analyzed to identify their reasons for success so they can be duplicated in other areas of the system.
  - Promotion Targets: Identify the specific market served by these routes and conduct targeted advertising promotions.
  - Re-Design Targets: A market for this service does exist, but the current route design is not meeting the needs of the target market. Adjustments to the route should be considered for implementation, including changes to the segments served, trip frequencies, and hours of operation.
  - Poor Performers: Insufficient market demand exists to justify these services. Consideration should be made for discontinuance if, after identification, the load factor does not improve after 90 days.

- *Use ExTRA to Locate the Enemy*. JTA uses Existing Transit Route Analysis (ExTRA) to process the APC data and provide summary information on route performance, including route load factor. ExTRA was used in FY 1998 to analyze existing routes and to investigate where people ride and when they ride. The results were specific proposals to re-design routes. Beginning in January 2000, many of these proposals were fully implemented to re-design the Southside service area. In July 2000, the first full re-alignment of services in the Arlington service area, without the intention of expanding service, was implemented. In July 2001, the Westside service was fully re-aligned, followed by a three-phase re-design of the Northside services between 2002 and 2003.

- *Interline Radial Routes*: Beginning in April 1999, JTA interlined a majority of radial lines that operate together through Downtown. Interlining enables customers to travel across town without having to change buses or pay an additional fare. This is important because JTA does not offer a transfer rate. Although PT dropped to some degree for some interliners due to the elimination of transfers between the interlining routes, PM increased significantly.

JTA strongly believes that it is winning the war on air with this five-element strategy. The central element of the strategy has been the collection and use of PM data for monitoring, evaluating, and designing its bus services. What has made all this possible is the APC technology. Here are some of the tangible benefits. From 1998 through 2003, the PT for its bus system grew only 1 percent, but the PM gained 41 percent. Furthermore, its PT-based productivity at the system level declined during the same period, but its PM-based productivity improved: 3 percent for PM per revenue mile and 34 percent for PM per revenue hour.

SUMMARY AND CONCLUSION

The paper builds a case for using passenger mile (PM) data in transit planning and fund allocation by comparing perceptions versus reality on the collection and usage of PM data. The perceptions are: 1) determining PM is difficult; 2) determining PM is expensive; 3) PM data are unreliable; 4) using PM data in fund allocation favors transit agencies serving longer trips; and 5) PM data are not useful for transit planning. But the reality is a much more positive picture:

- *Determining PM is easier than perceived.* Transit agencies that currently determine both PM and PT through sampling would still need to sample even if PM data were no longer required for the NTD. These transit agencies can do better when PM data still are required by using customized sampling plans rather than FTA-approved sampling plans. On the other hand, transit agencies that currently determine only PM through sampling would not need to sample if PM data were no longer required for the NTD. However, many of these agencies currently still use FTA-approved sampling plans for determining PM and unnecessarily over-sample in many cases as a result. For all agencies, new technologies will even the levels of difficulty in determining PM relative to PT.

- *Determining PM is less expensive than perceived.* FTA can do a better job of providing user-friendly tools for transit agencies to develop alternative sampling techniques on their own without the need to hire outside statisticians. The literature has many alternative sampling techniques for improving sampling efficiency or for reducing administrative costs over the FTA-approved sampling plans. The problem is that much of this literature is too complex and theoretical for most transit agencies to apply directly. Chu and Ubaka (2004) have made a first step toward that end by developing a practical guide and Excel-based templates for transit agencies to customize sampling plans to the conditions of their own fixed-route bus services.

- *PM data are more reliable than perceived.* The majority of transit agencies that currently report a 100-percent count of unlinked passenger trips (PT) to the NTD still use FTA-approved sampling plans to estimate average passenger trip length (TL). For many of these agencies, their PM estimates achieve far higher confidence and precision levels. This happens because they unnecessarily over-sample for FTA's 95-percent confidence and 10-percent precision levels when they use FTA-approved sampling plans. In the near future, reliability can be improved for transit agencies that directly count PM using new technologies such as APCs. Reliability also can be improved for transit agencies that directly count PT and use new technologies to estimate TL.

- *Using PM in fund allocation can be neutral*. Whether and the degree to which using PM data in fund allocation favors one group over another depends on how PM data are used in the allocation formula. Using PT alone as a measure of ridership in fund allocation favor agencies serving shorter trips, but using PM alone favors agencies serving longer trips. However, using both PT and PM in a symmetrical way neutralizes these extreme effects of trip length on fund allocation.

- *PM data are useful for transit planning*. PM data are already widely used by non-operating agencies at the federal, state, and local levels for transit planning and fund allocation. Some operating agencies also have been using PM data. The full potential of PM data for operating agencies will be increasingly realized with a wider deployment of new technologies that allow automated collection of a large amount of data at relatively low costs.

It is time for the transit industry to reconsider using PM data for transit planning and fund allocation. Just as it has benefited from using PT data, the transit industry can benefit from using PM data for transit planning and fund allocation. The Jacksonville Transportation Authority (JTA) of Florida is an example of using PM data collected with new technologies and benefiting from doing so. JTA "declared a war" on empty buses during the mid-1990s with a five-element strategy. The central element of the strategy has been the collection and use of PM data for monitoring, evaluating, and designing its bus services. What has made all this possible is the APC technology. Switching from PT to PM as a key performance measure positively altered JTA's performance image. From 1998 through 2003, the PT for its bus system grew only 1 percent, but the PM gained 41 percent; its PT-based productivity declined during the same period, but its PM-based productivity improved by 3 percent for PM per revenue mile and 34 percent for PM per revenue hour.

REFERENCES

Barry, Virginia (1993). Ongoing Use of Automatic Passenger Counters for Route Planning. In Symposium Papers for the Operational and Service Planning Symposium, December 8-13, 1993.

Bertini, Robert L., and Ahmed El-Geneidy (2003). Generating Transit Performance Measures with Archived Data. Transportation Research Record 1841: 109-119.

Boyle, Daniel K (1998). Passenger Counting Technologies and Procedures, TCRP Synthesis 29. Transportation Research Board, Washington, D.C.

Bremmer, Daniela (2002). Appendix A: WSTA Proposal for Public Transportation Performance Measurement. In Briefing Paper for January 2002 Transportation Commission Benchmark Committee Meeting.

Bureau of Transportation Statistics (2004). Federal Subsidies to Passenger Transportation. U.S. Department of Transportation, Washington, D.C.

Center for Urban Transportation Research (2002). Program Report for Resource for Advanced Public Transit Systems (RAPTS). University of South Florida, Tampa, Florida.

Chu, Xuehao (2004a). Ridership Accuracy and Transit Formula Grants. Transportation Research Board Paper No. 05-1573.

Chu, Xuehao (2004b). Another Look at FTA Approved Sampling Plans for Fixed-Route Bus Services. Transportation Research Board Paper No. 05-1548.

Chu, Xuehao, and Ike Ubaka (2004). A Guide to Customized Sampling Plans for National Transit Database Reporting. Journal of Public Transportation 7: 21-47.

Cox, Wendell (2005). St. Louis Public Transport Trend in Passenger Miles: 1990-1995, in Urban Transport Fact Book. Available at: http://www.publicpurpose.com/ut-stlpm.htm. Accessed on April 14, 2005.

Eastgate Regional Council of Governments (2003). Transit Development Program 2004-2008. Youngstown, OH.

FHWA (2003). 2002 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, Report to Congress. U.S. Department of Transportation, Washington, D.C.

Fielding, Gordon J. (1987). Managing Public Transit Strategically. Jossey-Bass Publishers, San Francisco, California.

Florida Department of Transportation (2000). Florida's Mobility Performance Measures Program. Tallahassee, Florida.

FTA (1999). Advanced Public Transportation Systems Deployment in the United States. U.S. Department of Transportation, Washington, D.C.

FTA (2000). Review of the National Transit Database Report to Congress. U.S. Department of Transportation, Washington, D.C.

FTA (2002a). Clean Fuels Formula Grant Program. Federal Register 67 (111): 40100-40109.

FTA (2002b). Reporting Instructions for the Selection of 5309 New Starts Program. U.S. Department of Transportation, Washington, D.C.

FTA (2003). Advanced Public Transportation Systems Deployment in the United States: Year 2002 Update. DOT-MA-26-7007-2003.3. U.S. Department of Transportation, Washington, D.C.

FTA (2004). 2004 Annual Reporting Manual. U.S. Department of Transportation, Washington, D.C.

Fulton County (2000). Interim Fulton County Comprehensive Transportation Plan. Atlanta, GA.

Furth, Peter G (2000). Data Analysis for Bus Planning and Monitoring, TCRP Synthesis 34. Transportation Research Board, Washington, D.C.

Furth, Peter G., and Brian McCollom (1987). Using Conversion Factors to Lower Transit Data Collection Costs. Transportation Research Record 1144: 1-6.

Furth, Peter G., Brendon J. Hemily, Theo H.J. Muller, and James G. Strathman (2003). Uses of Archived AVL-APC Data to Improve Transit Performance and Management: Review and Potential. Transit Cooperative Research Program, Washington, D.C.

Furth, Peter G., Keith L. Killough, and Gary F. Ruprecht (1988). Cluster Sampling Techniques for Estimating Transit Patronage. Transportation Research Record 1165: 105-114.

Garrett, Mark, and Brian Taylor (1999). Reconsidering Social Equity in Public Transit. Berkeley Planning Journal 13: 6-27.

General Accounting Office (1979). Analysis of the Allocation Formula for Federal Mass Transit Subsidies. Washington, D.C.

JTA (2004a). JTA Transit Development Plan: FY2005-FY2009. Jacksonville, FL: Jacksonville Transportation Authority.

JTA (2004b). JTA's Successful Ridership Turnaround. Presentation at Florida Transit Planning Network Technology and Planning Tools Workshop, January 21, 2004.

Metroplan Orlando (2002). Performance Measures: Orlando Regional Transit Systems Plan Update, Technical Memorandum No. 2. Orlando, Florida.

North Jersey Transportation Planning Authority (2002). Localized Congestion Management System Performance Goals for Northern New Jersey. Newark, NJ.
SANDAG (2004). Individual Route Reports. Available at http://cart.sandag.org/pcp/helpdoc.htlm. Accessed on August 18, 2004.

Smith, Robert L., Jr. (1983), Innovation and Incremental Improvement in Bus Transit Passenger Data Collection, Final Report, prepared for Urban Mass Transportation Administration, U.S. Department of Transportation.

Taylor, Brian, Peter Haas, Brent Boyd, Daniel Baldwin Hess, Hiroyuki Iseki, and Allison Yoh (2002). Increasing Transit Ridership: Lessons from the Most Successful Transit Systems in the 1990s. The Mineta Transportation Institute, San Jose, CA.

Thompson, Gregory L. (1999). Transit Operations Analysis of New Section 5307 Agencies. Florida Department of Transportation, Tallahassee, Florida.

Urban Mass Transportation Administration (UMTA) (1988), Sampling Procedures for Obtaining Fixed Route Bus Operating Data Under the Section 15 Reporting System, Circular UMTA-C-2710.1A, U.S. Department of Transportation.

USDOT (2003). DOT Performance Plan FY2004. Available at http://www.dot.gov/PerfPlan2004/index.html. Accessed on April 13, 2005.

Victoria Chaney and Kathryn Derr (1996). Liability Cost and Risk Analysis Studies. FTA-94-3115. Federal Transportation Administration, Washington, D.C.

Washington State Department of Transportation (2005). Transportation Benchmarks. Available at http://www.wsdot.wa.gov/accountability/benchmarks/default.htm. Accessed on April 14, 2005.