U. S. Department
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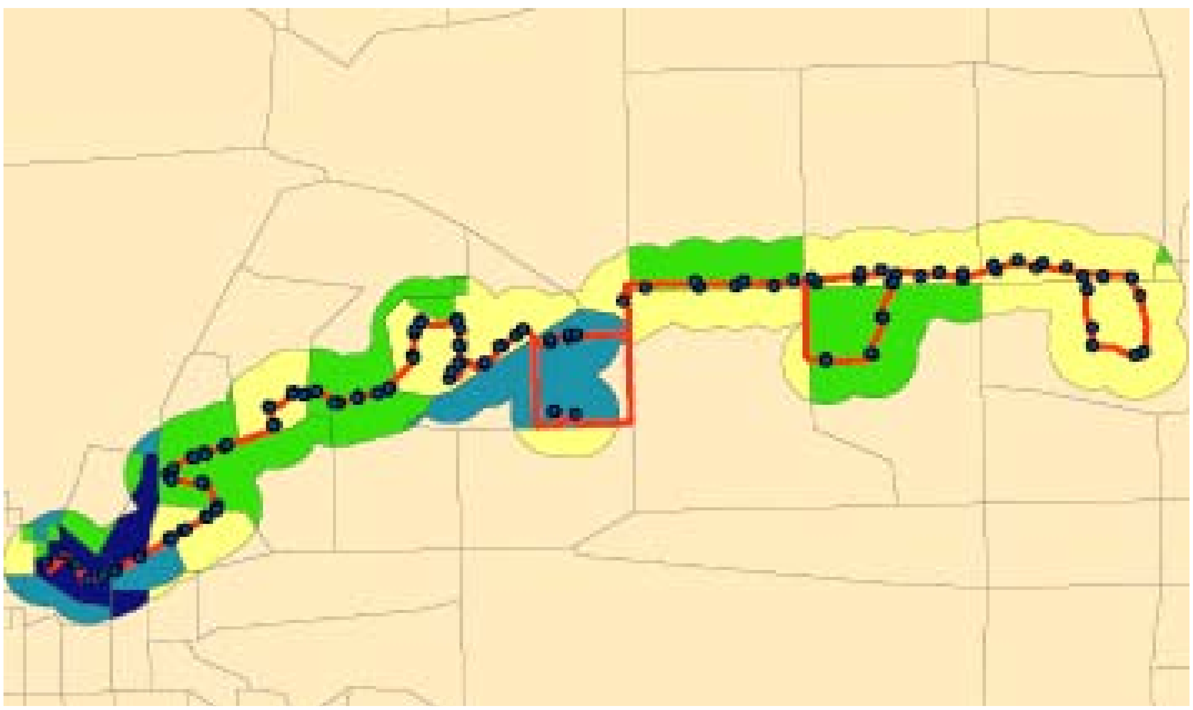
Federal Transit
Administration

Use of Geographic Information Systems for Transit Performance Measurement



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The results of the survey revealed a distinct gap between agencies believing the technologies are useful and agencies actually implementing them. The National Transit Database (NTD) provided agency size and revenue data which, matched with the surveyed agencies, demonstrated a sharp contrast in regards to an agency's technology use and its size or revenue generated. One reason that may discourage agencies from implementing GIS and other technologies is a lack of procedures and methods for implementing GIS for performance evaluation.

This study also includes a step-by-step guide to using GIS for performance assessment at the system and route level of a transit agency. The guide uses demographic data from the United States Census Bureau and geographic data from Waukesha Metro's transit system to give visual representations and provide examples of performance measures which can be analyzed with GIS

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Use of Geographic Information Systems for Transit Performance Measurement

October, 2006

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This study addresses the use of Geographic Information Systems (GIS) for transit performance measurement. Transit agencies that are members of the American Public Transportation Association (APTA) were contacted via survey to determine the use of performance measures, GIS, and other technologies such as Automatic Vehicle Locators (AVL) and Automatic Passenger Counters (APC).

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This study also includes a step-by-step guide to using GIS for performance assessment at the system and route level of a transit agency. The guide uses demographic data from the United States Census Bureau and geographic data from Waukesha Metro's transit system to give visual representations and provide examples of performance measures which can be analyzed with GIS.

ACKNOWLEDGMENTS

We would like to thank the people at transit agencies around the country that helped us with the survey portion of this project.

The descriptive material about performance indicators was adapted from a NTI course "Improving Transit System Performance: Using Information Based Strategies" developed at the University of Wisconsin-Milwaukee 1996-98. This material was written by Jack Reilly of the Capital District Transportation Authority (Albany, N.Y.), Edward Beimborn of the University of Wisconsin-Milwaukee and Robert Schmitt of RTR Associates in Pittsburg.

This report was developed as part of work being conducted by the Great Cities University consortium under the lead of the University of Alabama at Birmingham using funds provided by the Federal Transit Administration of the U.S. Department of Transportation.

The opinions expressed are the product of independent university work and not necessarily those of the sponsoring agencies or of the agencies supplying data for the project.

TABLE OF CONTENTS

INTRODUCTION

It is important for public transit agencies to measure transit performance easily and accurately. This fact is emphasized by Transit Cooperative Research Program Report (TCRP 88)[1], which will be used for much of the support of this paper. This report outlines three reasons for measuring performance. First, it is required for transit agencies as a condition for federal funding. Secondly, it is useful for a transit agency to assess its performance in order to maintain and improve their service. And thirdly, accurate information is needed for decision-making bodies to oversee transit service. The report sums up the use of performance measures by stating that they "can provide perspective, understanding, and context to what has gone on and what is going on within and organization" [2]. The easier it is to extract these measures the less time and money it will take to produce them and also for others to reproduce them for their purposes. So, obviously if this analysis can be done easily and accurately it is to the benefit of everyone involved.

There are a number of critical problems with the current methods of measuring transit performance. First, the ways of collecting data on performance have been an issue. Bertini and El-Geneidy, in "Using Archived Data to Generate Performance Measures"[3], state that it has been "difficult and costly to collect comprehensive performance data". They go on to say that agencies have had to use "limited, general, aggregate measures for reporting performance to external funding and regulatory agencies". Second, each agency must create its own way of measuring and implementing a system to assess the performance of their agency. Transit agencies would benefit by uniform ways to measure and assess performance that will simplify the data input and easily produce comprehensive reports on their performance.

The purpose of this report is to examine how transit performance measurement could be enhanced through the use of geographic information systems (GIS). The importance of GIS use is that it allows for easy, accurate measurement of transit performance. According to "Internet GIS and its Applications in Transportation", an article written by Peng and Beimborn[4] of the University of Wisconsin-Milwaukee, GIS "is being used to integrate, analyze and display spatial data". This use can be applied to transit using the proper data to show the effectiveness of a transit system.

This report will focus on the use of Geographic Information Systems (GIS) for measuring the performance of transit systems. The report will begin by defining transit performance and illustrating how it is measured and address issues with transit performance and demonstrate the positive aspects of GIS use in transit performance assessment. Next, the data necessary for proper implementation and analysis will be identified and discussed. Then, state of the practice within transit agencies will be examined through the use of surveys,

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[1] Transit Cooperative Research Program Report 88: A Guidebook for Developing a Transit Performance-Measurement System. FTA, Transportation Research Board, 2003.

[2] Ibid, p. 5

[3] Bertini, Robert L. and El-Geneidy, Ahmed. Using Archived Data to Generate Transit Performance Measures. Transportation Research Board. November 2002. pp. 1-24.

[4] Beimborn, Edward A. and Peng, Zhong-Ren. Internet GIS and Its Applications in Transportation. TR News, March-April, 1998. pp 1-10.

both direct and online, of transit agencies across the nation. The final topic will present a case study of the use of GIS as a means of transit performance assessment. A conclusion of the report will summarize our findings and provide a guide to further studies would be helpful to advance the understanding of this topic.

TRANSIT PERFORMANCE MEASURES[5]

Transit performance is very important to an agency in order to have a system that is as efficient and attractive as possible. Performance can be measured by numerous indicators. A performance indicator is a measure, usually quantitative, which reveals information about certain characteristics of a service. Sometimes the measure is a ratio of two other measures. For example, miles per hour is a measure of the average vehicle (bus) miles traveled per hour. It is composed of total vehicle miles traveled divided by the total hours of operation in travel. With careful, precise measurement and analysis, these performance indicators can reveal the level of effectiveness and efficiency of the transit system.

The purposes of measuring transit performance are abundant. Robert P. Schmitt, in his "Service Evaluation and Monitoring"[6], gives the goals of transit performance measurement. There are six of them, according to Schmitt:

1. To control costs and ensure the integrity of the system,
2. To justify changes in service levels,
3. To maintain or improve the quality of service,
4. To monitor subcontractors,
5. To guide marketing efforts, and
6. To report the status of transit service performance to policy boards.

The Transit Cooperative Research Program has created a number of reports that deal with transit performance issues. Of these, two of them have a significant relevance to our research. Both TCRP Report 88[7] and TCRP Report 100[8] have provided very useful information on transit performance. TCRP 88 "A Guidebook for Developing a Transit Performance-Measurement System" was published in 2003. TCRP 100 is the "Transit Capacity and Quality of Service Manual"[9] and was published in its second edition in 2003. The TCRP 88 method of defining and measuring transit performance requires looking at the performance from different points of view. The viewpoints are those from the customer, the community, the agency, and the driver/vehicle.

The first viewpoint is that of the customer. The customer is very important, as it is the customer who uses transit and for whom it was created for. According to the report, the customer has two main concerns; "service availability, and the comfort and convenience of service when it is available".
There are four factors that affect service availability:

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[5] This material is adapted from a NTI course "Improving Transit System Performance: Using Information Based Strategies" developed at the University of Wisconsin-Milwaukee 1996-98. This material was written by Jack Reilly of the Capital District Transportation Authority (Albany, N.Y.), Edward Beimborn of the University of Wisconsin-Milwaukee and Robert Schmitt of RTR Associates in Pittsburg.

[6] Schmitt, Robert P. Service Evaluation and Monitoring. Report prepared for the Pennsylvania Department of Transportation,

[7] TCRP 88, op.cit

[8] Transit Cooperative Research Program Report 100: Transit Capacity and Quality of Service Manual, Second Edition. FTA, Transportation Research Board, 2003. 622 pages.

[9] ibid

- spatial availability (where service is and whether customer can get to it),
- temporal availability (when service is available),
- information availability (customer is informed on how to use service), and
- capacity availability (space is available for trip).

With comfort and convenience, some factors that a transit agency has some control over include:
- service delivery (frequency of service),
- travel time (transit trip time versus other modes),
- safety and security (risks of being injured or being a victim to crime), and
- maintenance (reliability of system's vehicles).

The second point of view is that of the community. Here the concern is with areas in which transit service "benefits the community as a whole" as well as the "costs and negative aspects" of transit service[10]. From the standpoint of community support, a transit agency does well to provide evidence of its performance and the way in which it deals with negative concerns.

The third viewpoint is that of the agency itself, which has a distinctly different view from the customers and community. The agency must constantly ensure that its operations run smoothly and is concerned with its organizational performance. It can use performance measures to guide its actions and should also be aware of customer and community concerns.

The final viewpoint comes from the driver or vehicle. Within it comes the need to gauge the interaction between transit and automobiles because the way they affect each other can determine the quality of transit service. The report suggests that "vehicle-oriented measures", taking into account the likely increased person occupancy on a bus, should be addressed when studying the impacts of transit and autos on each other.

In a system as complex as transit, hundreds of measures to assess performance could be developed. However, experience has shown a relatively small number of measures (usually no more than 20) can be used effectively. More than 20 can make it difficult for the end user to make an accurate judgment.

Considering the vast number of possible indicators, it will be helpful to classify performance measures into a smaller set of categories. In a study published in 1982, a classification of performance indicators was devised.[11] An abbreviated version of this classification is given below.

Financial Indicators

Expense

- Total Operating Expense (Cost) / Total Passenger Trips: This is a measure of how well the system is serving riders with available resources.
- Total Operating Cost / Vehicle Miles (or Vehicle Hours): Measures of productivity of

[10] TCRP 88, p 7

[11] Pennsylvania Department of Transportation, Rural Public Transportation Performance Evaluation Guide, Bureau of Public Transit (Harrisburg, PA: November, 1982), pp. 4-10.

transit service provision, which is useful in setting benchmarks or comparing services, including the services of peer systems.

- Administrative Expenses / Total Expenses: A measure of the appropriate balance between these two expenses. As a rule of thumb, administrative costs should not exceed 15-20 percent.

Revenue

- Total Revenue / Total Passenger Trips: A measure of the average revenue for a passenger trip.
- Total Fare Revenue / Total Revenue: An indicator of the percentage of revenue accounted for by fares.
- Revenue / Expense (Cost): Also called operating ratio or cost recovery. A measure of the degree to which operating expenses are covered by revenues.

Subsidy

- Total Subsidy / Total Vehicle Hours: The average subsidy per vehicle hour of service.
- Total Subsidy / Total Passenger Trips: A measure of the average subsidy for every passenger trip.

Non-Financial Indicators

Ridership

- Total Passenger Trips / Total Vehicle Hours: The average number of trips served per vehicle hour. A measure of transit productivity.
- Total Passenger Trips / Total vehicle Miles: A productivity measure useful for comparing services, especially in rural areas or on longer suburban routes.
- Elderly Passengers / Total Passengers: An indicator of the use of transit by elderly passengers. May be useful in designing stops and assigning equipment.
- Passenger Trips / Population of Service Area: An indicator of the level of transit use in an area.

Service Quality

- Number of Complaints / Number of Drivers: A rough measure of consumer dissatisfaction.
- Stops On-Time / Total Stops: A measure of on-time performance.
- Vehicle Miles / Road Calls: A measure of miles between road calls; a surrogate for fleet age and maintenance effectiveness.

Level of Service

- Revenue Miles / Revenue Hours: A measure of concentration of services.
- Vehicle Miles / Year: A useful measure for comparing level of service over time.
- Vehicle Hours / Year: A useful measure for comparing level of service over time and as an element in calculating additional indicators.

Safety

- Vehicle Miles / Vehicle Accidents: The number of vehicle miles between accidents, an important safety indicator.

- Avoidable Accidents per Year: A useful safety indicator and one often used for setting safety standards

The indicators may be expressed in many different ways depending on what the manager wants to measure. Total vehicle miles and revenue vehicle miles are different indices, they measure slightly different things; farebox revenue and total revenue also differ significantly in some systems. Most indicators are appropriate at the system and route level while others are useful primarily at the route level.

Performance indicators have two major uses. First, they may be employed to assess how well the system is doing with respect to the standards established by management. Second, they may be used to identify areas within the system that need attention or remedial action. Both of these approaches come together in the transit system evaluation process.

Business vs. Social Measures

Both business and social measures of transit service can be performed at the system, route or route segment, and even stop level. Most of the transit performance work to date using on-board data has focused on **business** measures of service (cost per customer transported, etc.). The recent advent of geographic information systems (GIS) has enabled transit analysts to make a number of **social** measurements of transit service. For example, coupled with a description of the service (stop lists, frequencies, etc.) an analyst can determine the proportion of households without autos served by daytime service, the proportion of households with direct access by transit to shopping and the proportion of jobs in the transit service territory[12]. The social mobility measures when coupled with more traditional business measures of transit service (revenue to cost ratio, for example) provide a more complete picture of transit performance in metropolitan areas. Through the use of these technologies one can estimate the cost to achieve certain levels of mobility.

Business Measures

The most important business measures to transit operators are resource utilization measures such as customer boardings per revenue mile or revenue hour. Other measures of some interest in this area include revenue to cost ratio or cost per customer transported. In fact, several transit systems have some type of service standards against which actual performance levels are measured.

Providing cost information below the route level requires the use of some type of cost allocation model. This can either be a short run avoidable cost model (to determine the short run impact of changes in the level of service) or fully allocated costs in which all system costs including short run avoidable costs and fixed costs are pro-rated among routes.

[12]Albert Gan, Ike Ubaka, et all, FTIS - Florida Transit Information System, Version 2004, Developed for the Public Transit Office, Florida Department off Transportation by the Lehman Center for Transportation Research, Florida International University, http://lctr.eng.fiu.edu/ftis/FTGIS.htm accessed 8-16-06

By using farebox data for example, one can develop business measures for routes in the system. The table below shows a set of measures for Saturday routes in a transit system.

TABLE 1: EXAMPLE OF ROUTE COMPARISON

CAPITAL DISTRICT TRANSPORTATION AUTHORITY
KEY INDICATOR SUMMARY
Saturday Total

Period: May

Route		Revenue/ Cost	Passengers/ Hour	Margin/ Passenger
2	West Albany	.26	14.2	$1.60
4	Pine Hills	.20	12.8	$1.98
3	Quail Street	.37	21.4	$1.23
8	Arbor Hill	.14	10.1	$3.15
14	Third Street	.28	16.1	$1.74
18	Delaware Avenue	.19	10.4	$2.24

Source: Capital District Transit Authority, Albany, N.Y.

Social Measures

While most of the work in system wide performance measures is focused on business measures, such as revenue to cost ratios, there is also a need for transit systems to use social indicators. Examples of these would include what proportion of households without autos has transit service of a specified quality. One particularly helpful social measure is an estimate of the number of households with particular social characteristics in a transit district within a quarter mile of a bus stop (this is a five minute walk at three miles per hour). For example, one can determine the proportion of households without autos served by daytime service, the proportion of households with direct access by transit to grocery stores and the proportion of jobs in the transit service territory.

It should be noted that different measures of transit accessibility could generate drastically different results. A quarter mile of air distance from a bus stop without considering the actual street network would over-estimate the accessibility of residents who may have to walk much longer than a quarter mile on the street network to access the bus stop. To address this issue, the Transit Level of Service software (TLOS) developed by the Florida Department of Transportation (Figures 1 and 2) provides a technique for measuring transit accessibility and availability of service based on actual street networks (walk buffers) and transit schedules rather than an air distance buffer. The software uses GIS to determine if transit service is, in fact, available to users at different times of the day and week at any location within the system's service area. Work with the TLOS system has indicated that far fewer individuals have 'adequate' transit service to meet their travel needs than had been previously thought[13]. Figures 1 and 2 compare the use of air distance buffers to the use of walk buffers for the Tallahassee Transit System. TLOS uses two distances, from residence and from job site, to determine the accessibility of a person to a transit stop. According to the data used in the TLOS software, the difference between the use of air distance buffers and the use of walk buffers was quite significant. For residences, the population served for the air distance buffer was about 19% greater than that served based on actual walk distance. For accessibility to job sites, that difference was over 75%. Table 2 shows the difference between the two methods for all routes and times available in the TLOS software for the Tallahassee Transit System.

TABLE 2: MEAN POPULATION AND JOBS SERVED BY AIR AND WALK BUFFERS

TALLAHASSEE TRANSIT SYSTEM
AIR DISTANCE BUFFER VS. WALK BUFFER
All routes and all times

Buffer Type	Population Mean	Job Mean
Air Distance	1,227	2,409
Walking Distance	699	2,027

N = 523,634

Source: TLOS, Tallahasse, F.L.

[13] Ausman, Jon, TLOS Demonstration, Urban Transportation Planning Short Course, Tampa, Florida, March, 2002

FIGURE 1: AIR DISTANCE BUFFERS FROM TRANSIT STOPS, 5 MINUTE DISTANCES, TALLAHASSEE TRANSIT SYSTEM

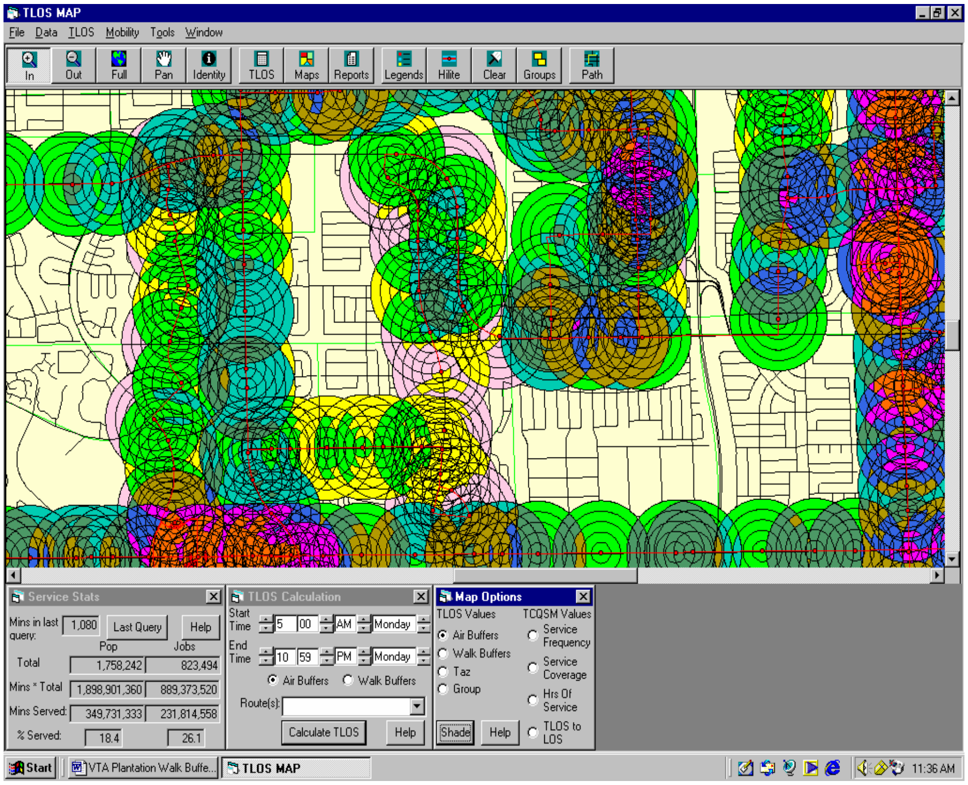
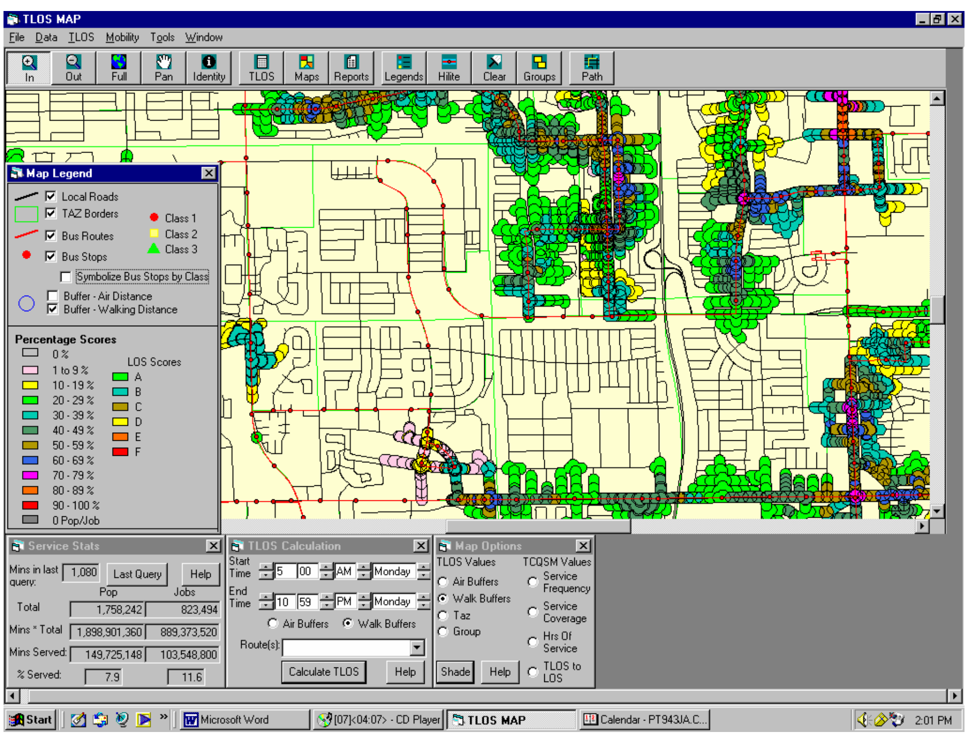


FIGURE 2: ACTUAL WALK BUFFERS FOLLOWING LOCAL STREET PATTERNS, TALLAHASSEE TRANSIT SYSTEM



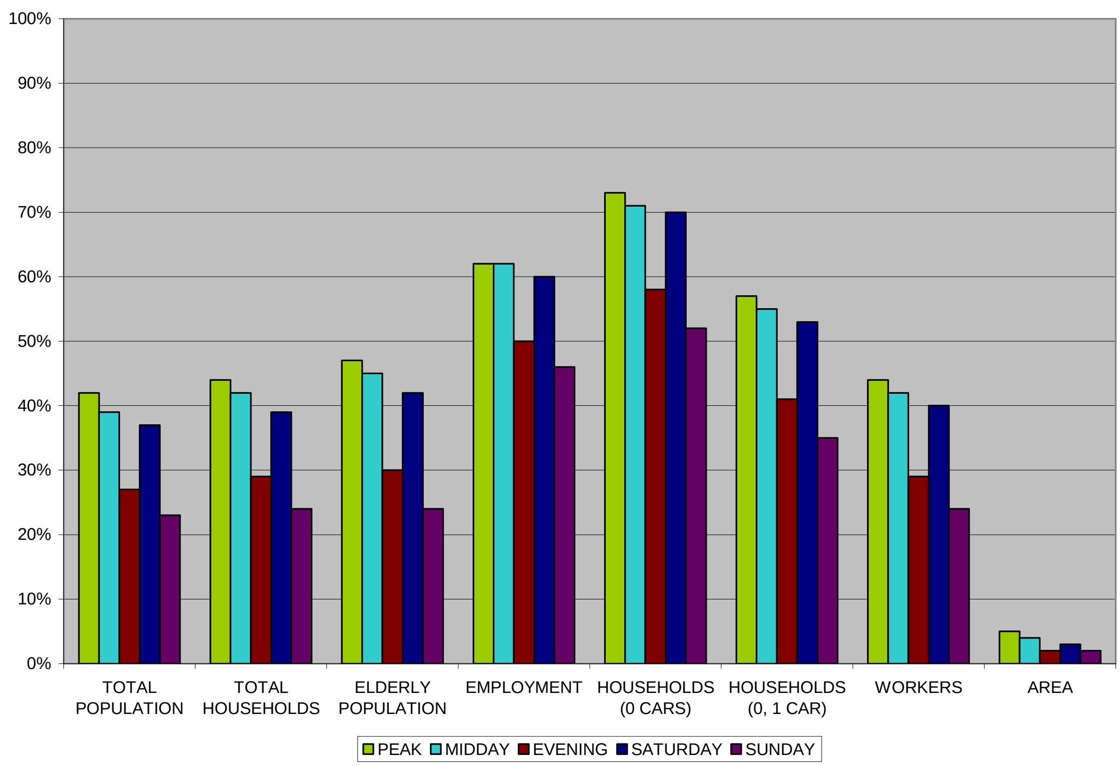
In other cases, the accessibility measure can identify the concentration of the captive riders. For example, Table 3, along with Figure 3, shows the system wide performance measures by service period. The table and figure show that although the transit service territory includes only 4% of the transit district, fully 73% of the households without autos are within 0.25 miles of a transit route.

TABLE 3: PROPORTION OF POPULATION IN SERVICE AREA BY SERVICE PERIOD

CHARACTERISTIC	TOTAL	PEAK	MIDDAY	EVENING	SATURDAY	SUNDAY
TOTAL POPULATION	100%	42%	39%	27%	37%	23%
TOTAL HOUSEHOLDS	100%	44%	42%	29%	39%	24%
ELDERLY POPULATION	100%	47%	45%	30%	42%	24%
EMPLOYMENT	100%	62%	62%	50%	60%	46%
HOUSEHOLDS (0 CARS)	100%	73%	71%	58%	70%	52%
HOUSEHOLDS (0, 1 CAR)	100%	57%	55%	41%	53%	35%
WORKERS	100%	44%	42%	29%	40%	24%
AREA	100%	5%	4%	2%	3%	2%

Source: Capital District Transit Authority, Albany, N.Y.

FIGURE 3: PROPORTION OF POPULATION IN SERVICE AREA BY SERVICE PERIOD



Social measures can also be made at the route level. By using geographic information systems, one can compute the number of households within 0.25 miles of the route, the distribution of auto ownership within the route's market area etc. Further, the characteristics of the **route** service can be compared with the characteristics of the **system** service area. The tables below illustrate this[14].

In practice, three kinds of measures are commonly used (TCRP 88). The first are revenue and cost measures. Examples include gross profit margin, net income, percent of revenue from fare box, and cost per rider/mile/trip. The second category is system and change monitoring. It can include secondary data such as inventory on hand, number of complaints, accidents per mile, and number of vehicle washings. Thirdly, there is customer satisfaction and loyalty. This must answer questions like does the service meet customers' expectations? Also, will customers recommend services or continue to repurchase or use the service?

TABLE 4: PERFORMANCE MEASURES OF ROUTE 50

Business Measures	
Passengers per hour	8.5
Cost per passenger	6.55
Public support cost (annual)	$105,633
Social Measures	
Households in service area	3,191
Households without autos in service area	270
Public support cost per household	$33
Public support cost per household w/o autos	$391

Source: Capital District Transit Authority, Albany, N.Y.

[14] Reilly, Jack "Improving Transit System Performance: Using Information Based Strategies" developed at the University of Wisconsin-Milwaukee 1996-98.

TABLE 5: RESIDENTIAL ROUTE ANALYSIS – ROUTE 50

Overall Route 50 Route Service Area

Key Indicators	Service Area	Area	Percent of total
Population density (pop/sq.mi.)	4,105	2,116	-
Percent of households without autos	13%	2%	-
Percent of households with 0,1 auto	43%	12%	-
Percent of population over age 65	13%	4%	-
Households without autos per sq. mi.	415	26	-
Percentage of region's workers living in route service area using transit	6%	0.2%	
Supplemental Indicators			
Total population	468,719	8,377	2%
Total area (sq. mi.)	264	7	3%
Total population over age 65	68,667	1,333	2%
Total households without autos	30,310	270	0.9%
Total workers	187,283	3,190	2%
Population over age 65 per sq. mi.	575	345	-
Workers per sq. mi.	1,675	236	-

Source: Capital District Transit Authority, Albany, N.Y.

Problems with the performance measurement

Assessing transit performance measurements using these indicators easily and accurately is important. But measuring these indicators is not an easy job, particularly the social indicators. Traditionally, general fare-box and payroll data are used to measure business performance indicators at the system level.

There are a number of problems with the current methods of measuring transit performance. As Bertini and El-Geneidy (2002) observed that it has been “difficult and costly to collect comprehensive performance data”. Therefore, transit agencies have had to use limited, general, aggregate measures to assess transit performance. Furthermore, each agency usually has to create its own way of measuring and implementing a system to assess the performance of their agency. Transit agencies may benefit by use of advanced technologies to simplify data collection and produce comprehensive reports on their performance.

Technologies like GIS, automatic vehicle location systems (AVL), and automatic passenger counters (APC) appear to have promise as ways to improve the measurement of transit performance. A key question for this report is: are transit agencies taking advantages of these technologies? This report explores the use of these technologies and how it relates to the size of the system and other factors.

The next section will report a survey about the actual usage of transit performance in transit agencies in the United States.

SURVEY OF TRANSIT PERFORMANCE MEASUREMENT IN TRANSIT AGENCIES

In order to understand the state of the practice in the use of transit performance measurement and the use of new technology in measuring transit performance, a survey was conducted for transit agencies in the U.S. The purpose of the survey was to determine the best practice of transit agencies across the country. It is split up into three parts: use of transit performance measures and measurement techniques, the use of GIS to measure transit performance, and the use of other technologies such as AVL and APC to measure transit performance.. The survey was sent to all of the transit agencies on the American Public Transportation Association membership list, totaling nearly 400 agencies. The agencies were given the option of returning the paper survey or filling out the same survey made available on the internet. Of the agencies surveyed 107 of them responded and the data collected from their surveys was compiled and coded for analysis.

A copy of the survey used is given in the appendix of this report. This section will present the findings of the survey.

Transit Performance Measures and Measurement Techniques

The questions in Part I of the survey were intended to determine the use of transit performance measurement by U.S. transit agencies. We wanted to know if and why transit performance measures are used. We also wanted to find out what the agencies feel are the most important transit performance measures that they use or would like to use. Another set of questions related to the collection of transit performance data. This includes sources of the data, how the data has been collected in the past, problems with collecting the data, and sources for analysis.

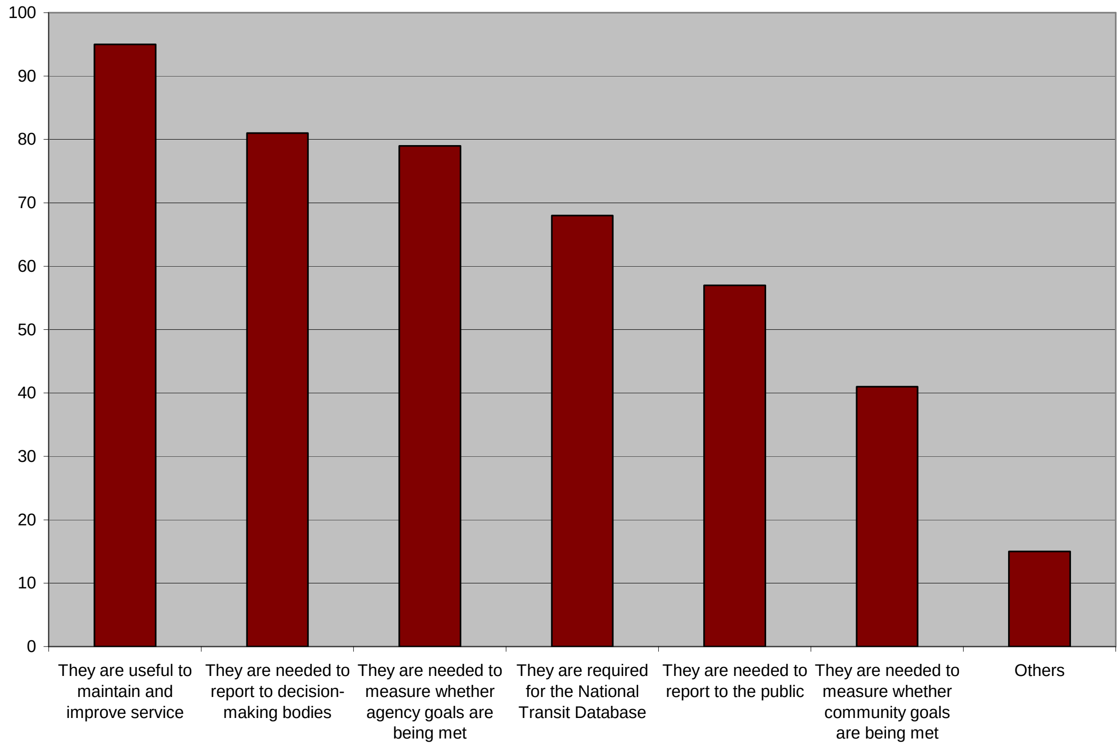
Of the 107 responses, 98 (91.6 %) say they use transit performance measures in their service and operation planning and evaluation, while 9 of the respondents did not. Follow-up questions were then asked for those that do use transit performance measures. When asked "why do you use transit performance measures?" the most popular response was that the measures are useful to maintain and improve service, as shown in Table 6 and Figure 4. The other two popular responses are that they are needed to report to decision-making bodies and to measure whether agency goals are being met.

TABLE 6: WHY PERFORMANCE MEASURES ARE USED

REASONS FOR TRANSIT PERFORMANCE MEASURES	COUNT	PERCENT	RANK
They are useful to maintain and improve service	95	96.94%	1
They are needed to report to decision-making bodies	81	82.65%	2
They are needed to measure whether agency goals are being met	79	80.61%	3
They are required for the National Transit Database	68	69.39%	4
They are needed to report to the public	57	58.16%	5
They are needed to measure whether community goals are being met	41	41.84%	6
Others	15	15.31%	7

**The total percentage does not add up to 100% because the question asked the respondents to check all that apply.*

FIGURE 4: WHY PERFORMANCE MEASURES ARE USED



The results from Table 6 show that transit performance measures are mainly used to improve services and assess agency goals. The need to report to the national transit database and to the public is also important, but to a lesser degree. Over four fifths of the agencies use transit performance measurement for business purposes, while social measures are used by about half of the respondents.

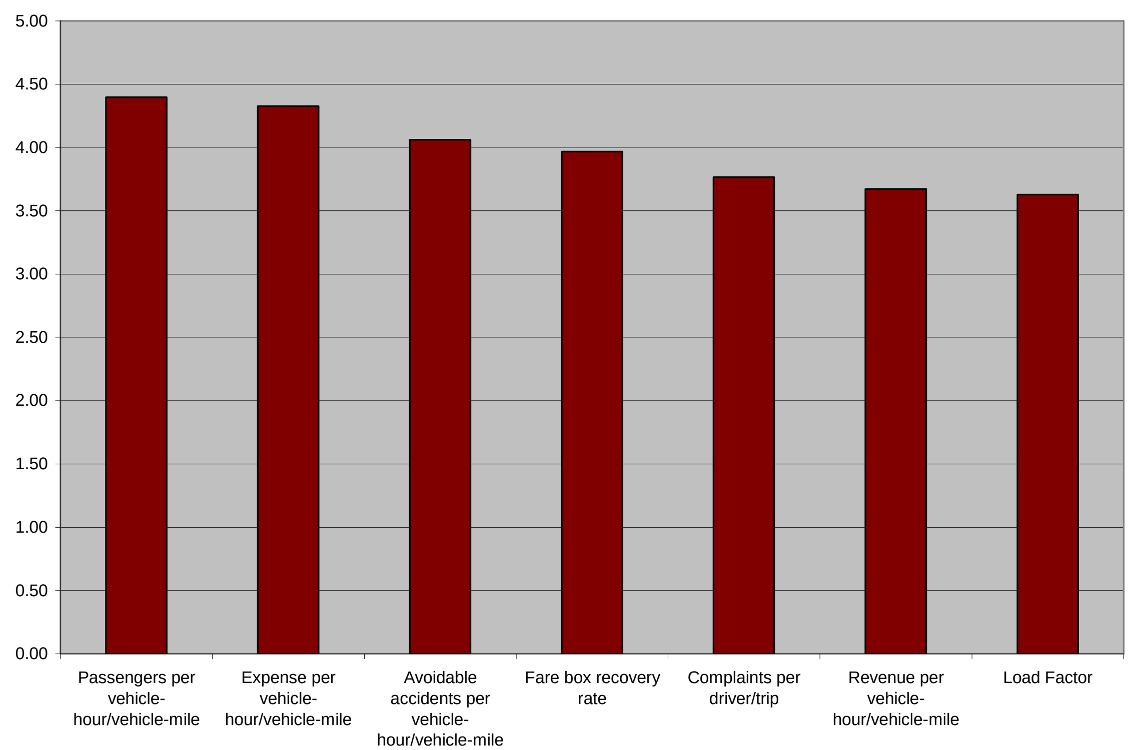
To obtain the most commonly used transit performance measures, we asked two questions. The first question asks the respondents to rank the 7 given performance indicators, including an open ended “other” factor. The respondents were asked to assess the transit performance indicators on a scale from 1 = “Not Important” to 5 = “Very Important". The scores obtained from each agency responding to the question were totaled and divided by the total number of responses to get the average score for each measure. Looking at Table 7 and Figure 5, the average scores indicate that the most important measures are passengers per vehicle-hour/vehicle-mile (4.40) and Expense per vehicle-hour/vehicle-mile (4.33). The lowest two scores were Revenue per vehicle-hour/vehicle-mile (3.67) and Load Factor (3.63). All measures scored relatively high.

TABLE 7: IMPORTANCE OF SPECIFIC MEASURES

MEASURE	1	2	3	4	5	AVERAGE
Passengers per vehicle-hour/vehicle-mile	0	0	7	45	46	4.40
Expense per vehicle-hour/vehicle-mile	1	2	13	30	52	4.33
Avoidable accidents per vehicle-hour/vehicle-mile	5	5	13	31	44	4.06
Fare box recovery rate	4	6	18	29	39	3.97
Complaints per driver/trip	5	8	23	31	31	3.77
Revenue per vehicle-hour/vehicle-mile	6	8	22	38	24	3.67
Load Factor	3	7	28	44	15	3.63
Others:						
Maintenance measure					2	5.00
On-time performance measure				3	4	4.57
Ridership measure				1	1	4.50
Cost measure			1	1	3	4.40
Road calls measure		1			2	4.00
Connectivity				1		4.00
Customer satisfaction measure				1		4.00
Debt/service coverage ratio				1		4.00
Wheelchair passenger trips				1		4.00

**Question: How important are the following transit performance indicators? (Circle the number on a 5 point scale from 1 = "Not Important" to 5 = "Very Important")*

FIGURE 5: IMPORTANCE OF SPECIFIC MEASURES



The next question was aimed at determining the five most commonly used or most important performance indicators without pre-specified indicators. The question was "What do you feel are the 5 most important performance measures that your system uses?" In response to this we received 37 different measures with 442 total responses. Respondents generally provided specific measures which we grouped according to broader categories. Each of the six types of measures listed is perceived to be important to transit performance evaluation.

Ridership measures were deemed most important, as indicated by the number of responses and the percentage of total responses received. These measures relate to the number of passengers that choose to use transit over other forms of transportation. The cost measure, second on the list, is also an important indicator of performance, especially when normalized by service mileages, hours, trips, or passengers. These measures indicate the expense required to provide transit services to transit users. Altogether, the results of this question indicate the measures that are viewed as most important to the nation's transit agencies. These top two measures, as well as farebox recovery rate, are highly consistent with the previous question.

The importance of other measures is not consistent with the previous question. For example, the accidents indicator is ranked as the least important and commonly used indicator in this question, but ranks third in the last question. This may indicate that some transit agencies consider avoidable accident rates important, but do not actually measure them. One possible explanation is that the data required are difficult to collect.

1. Ridership
    - Received 107 responses (24.21%)
    - Examples of measures included: Average/annual ridership, Boardings per hour, Passengers per mile (or per hour or per trip)
2. Cost
    - Received 70 responses (15.84%)
    - Examples of measures included: Cost per mile (or per hour or per passenger), Expense per mile/hour/passenger, Operating cost per hour (or per trip)
3. Farebox Recovery Rate
    - Received 44 responses (9.95%)
    - Examples of measures included: Cost recovery, Farebox recovery rate/ratio/standard
4. On-Time Performance
    - Received 43 responses (9.73%)
    - Examples of measures included: On-time performance rate/percentage
5. Customer Satisfaction
    - Received 41 responses (9.28%)
    - Examples of measures included: Complaints per boarding (or per driver or per mile or per passenger or per route or per trip), Compliments/comments, Customer satisfaction
6. Accidents
    - Received 39 responses (8.82%)
    - Examples of measures included: Accidents per mile (or per 100,000 miles), Avoidable/preventable accidents per mile (or per 100,000 miles)

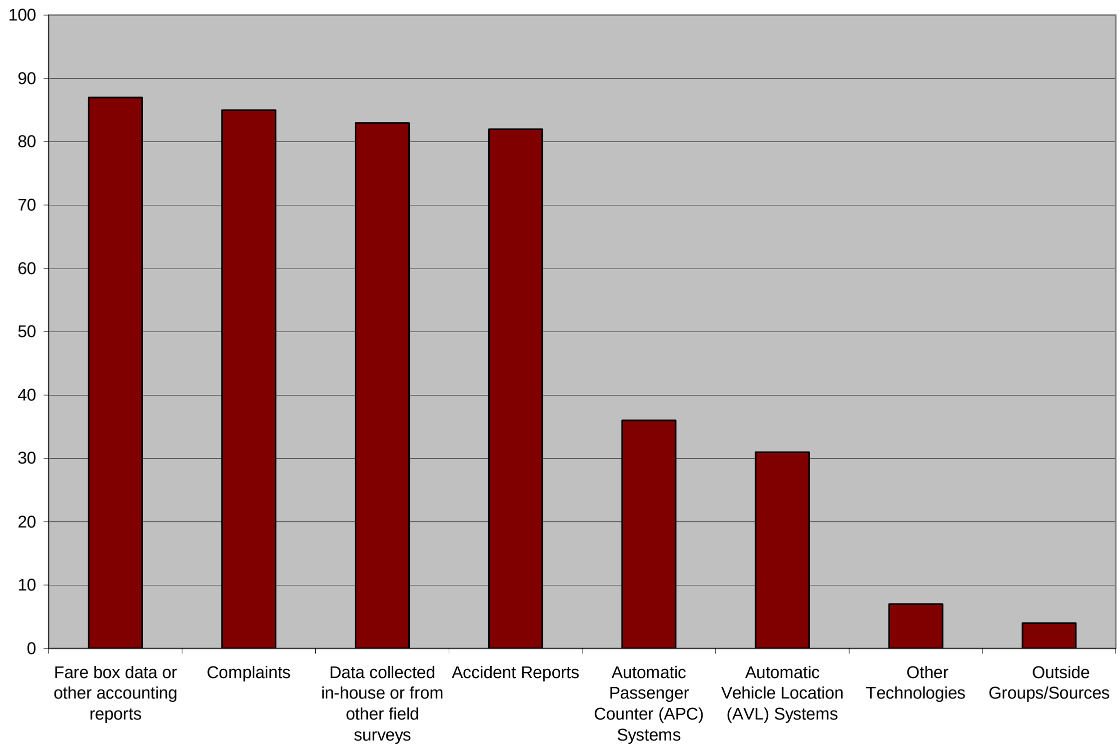
Table 8 and Figure 6 show the various sources of data and how popular they were among the respondents. The most common data sources of data are farebox data or accounting reports like payroll data, followed by passenger complaints, data collected from the field, and accident reports. About a third of the respondents indicated a use of AVL and APC data, or data generated from some other technologies.

TABLE 8: SOURCES OF DATA

SOURCE	COUNT	PERCENT	RANK
Fare box data or other accounting reports	87	88.78%	1
Complaints	85	86.73%	2
Data collected in-house or from other field surveys	83	84.69%	3
Accident Reports	82	83.67%	4
Automatic Passenger Counter (APC) Systems	36	36.73%	5
Automatic Vehicle Location (AVL) Systems	31	31.63%	6
Others			
Other Technologies	7	7.14%	7
Outside Groups/Sources	4	4.08%	8

**Question: What are your sources of data? (Check all that apply)*

FIGURE 6: SOURCES OF DATA



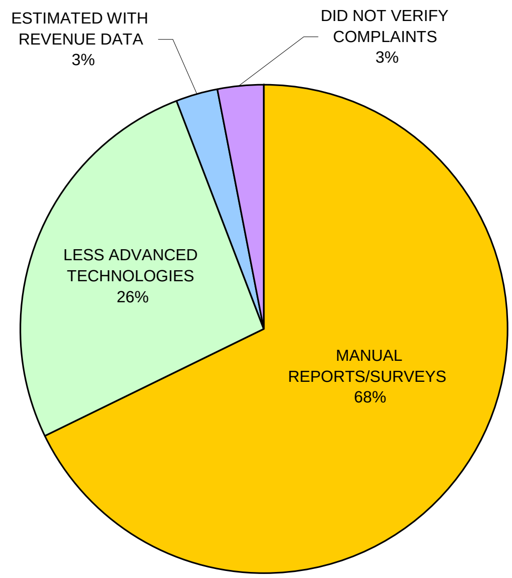
To identify the changes of data collection methods, the survey asked if the data was collected differently in the past. Roughly 2/3 of respondents used the same way of collecting data as in the past. Of those who did collect data differently, we asked them to provide the methods previously used. Table 9 and Figure 7 illustrate the previously used methods and show that it was most common for agencies to use manual methods and less advanced technologies.

TABLE 9: PREVIOUS COLLECTION METHODS

METHOD	COUNT	PERCENT	RANK
MANUAL REPORTS/SURVEYS	23	67.65%	1
LESS ADVANCED TECHNOLOGIES	9	26.47%	2
ESTIMATED WITH REVENUE DATA	1	2.94%	3
DID NOT VERIFY COMPLAINTS	1	2.94%	3
	34	**100.00%**	

**Question: If so, what method(s) did you use? (List all methods)*

FIGURE 7: PAST COLLECTION METHODS



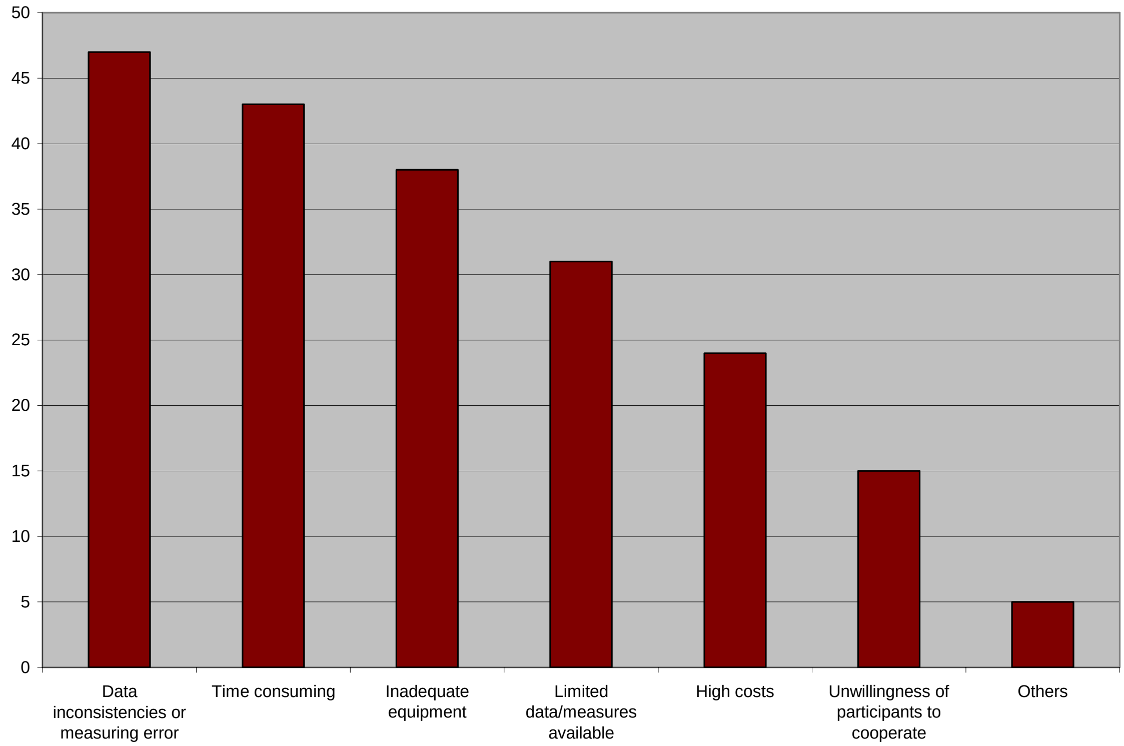
Question six asked about problems that have been encountered in collecting performance data. This question aimed to find the problems associated with gathering data for transit performance assessment. Just over 3/4 of agencies (65 out of 86) reported that they had experienced data collection problems. A follow-up question asked what the problems were that had occurred. These results are shown in Table 10 and Figure 8. Data inconsistency, time requirements and lack of proper equipment were cited by a majority of respondents as problems.

TABLE 10: SPECIFIC DATA COLLECTION PROBLEMS

PROBLEM	COUNT	PERCENT	RANK
Data inconsistencies or measuring error	47	72.31%	1
Time consuming	43	66.15%	2
Inadequate equipment	38	58.46%	3
Limited data/measures available	31	47.69%	4
High costs	24	36.92%	5
Unwillingness of participants to cooperate	15	23.08%	6
Others	5	7.69%	7

**Question: If so, what problems have occurred? (Check all that apply)*

FIGURE 8: SPECIFIC DATA COLLECTION PROBLEMS



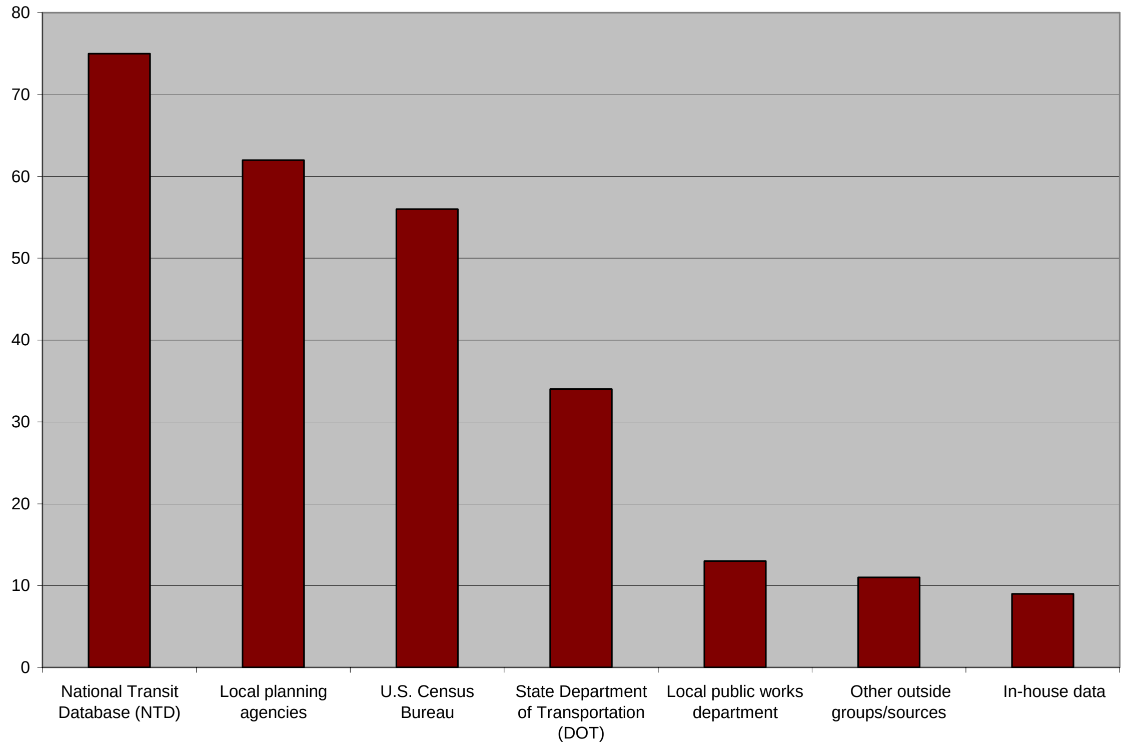
In addition, we asked what additional existing data are used for analyzing transit performance. The results are shown in Table 6 and Figure 9. It shows that the National Transit Database (NTD), local planning agencies, and the U.S. Census were the most commonly used data sources.

TABLE 11: DATA SOURCES USED FOR ANALYSIS

SOURCE	COUNT	PERCENT	RANK
National Transit Database (NTD)	75	76.53%	1
Local planning agencies	62	63.27%	2
U.S. Census Bureau	56	57.14%	3
State Department of Transportation (DOT)	34	34.69%	4
Local public works department	13	13.27%	5
Others			
Other outside groups/sources	11	11.22%	6
In-house data	9	9.18%	7

* *The survey asked to check all that apply. Therefore, the total does not add to 100%.*

FIGURE 9: DATA SOURCES USED FOR ANALYSIS



Summary of part 1: Overall, the results of the first part of the survey show that most transit agencies use transit performance measures to evaluate the performance of their transit systems. The major purpose of using transit performance measures is to improve transit services, while a secondary goal is satisfying reporting requirements. The most commonly used transit performance indicators are ridership- and cost-related measures, particularly, passengers per vehicle-hour/vehicle mile and expense per vehicle-hour/vehicle mile. Other important measures include farebox recovery, on-time performance, customer satisfaction, and accidents.

Furthermore, the survey indicates that most current methods of data collection and analysis have problems. About one third of transit agencies have started to change the way they collect performance data, moved away from manual methods to more automated, technology-based methods, and started to use higher level technologies such AVL and APC for data collection.

Use of GIS to Measure Transit Performance

The questions in Part II of the survey were aimed at determining the use of Geographic Information Systems (GIS) for transit performance assessment and to find out how transit agencies perceive the benefits of GIS. The reason that we want to focus on the use of GIS is because GIS has a high potential for use to integrate, analyze and report transit performance efficiently and effectively. We wanted to know if GIS is readily accessible to transit agencies and, if accessible, is it put to use? Also, how do transit agencies perceive it as a transit performance assessment tool? This relates to performance data collection as well as to the use of GIS to analyze or report that data. The difference in the use of GIS at the system and route levels was also included in this part of the survey.

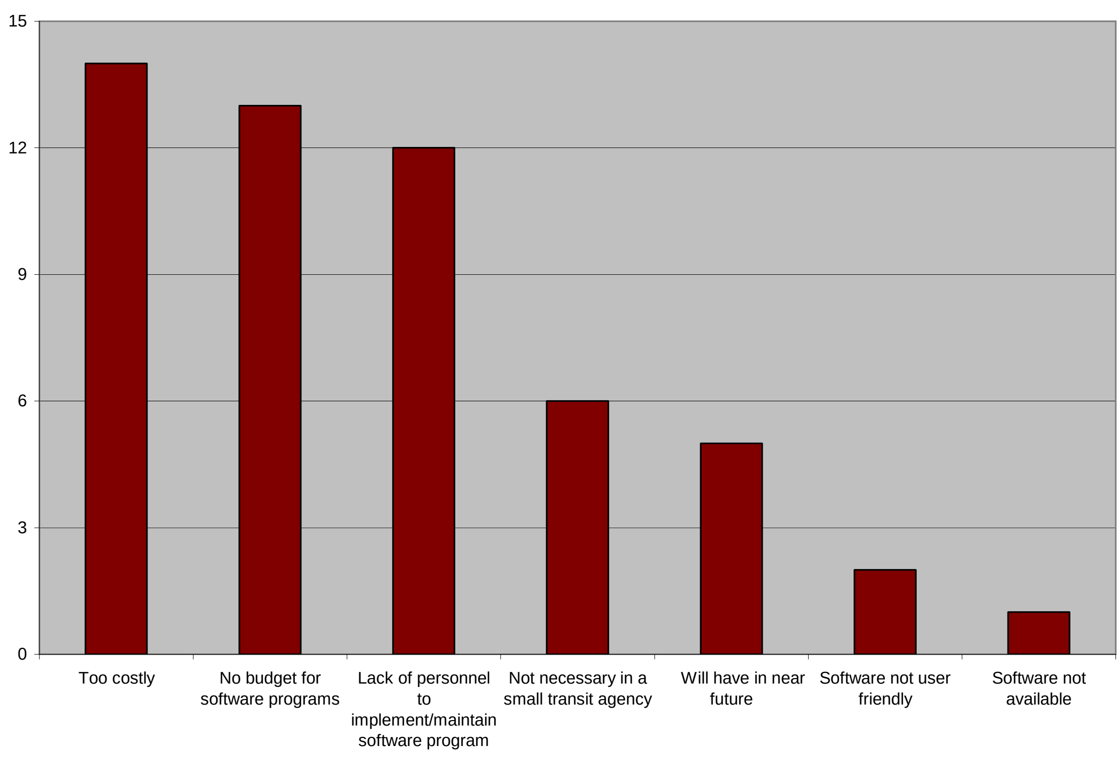
The survey indicated that GIS technology is available at about two-thirds of the agencies. The major reasons for not having GIS are high cost, lack of budget for software purchase, and lack of technical personnel to operate GIS. In addition, some small transit agencies felt that GIS was not needed due to the size of their size. Table 12 and Figure 10 show these results.

TABLE 12: REASONS WHY GIS IS NOT ACCESSIBLE

REASON FOR NO GIS	COUNT	PERCENT	RANK
Too costly	14	40.00%	1
No budget for software programs	13	37.14%	2
Lack of personnel to implement/maintain software program	12	34.29%	3
Not necessary in a small transit agency	6	17.14%	4
Others			
Will have in near future	5	14.29%	5
Software not user friendly	2	5.71%	6
Software not available	1	2.86%	7

**Question: If no, why do you not have a GIS software program that you can use? (Check all that apply)*

FIGURE 10: REASONS WHY GIS IS NOT ACCESSIBLE



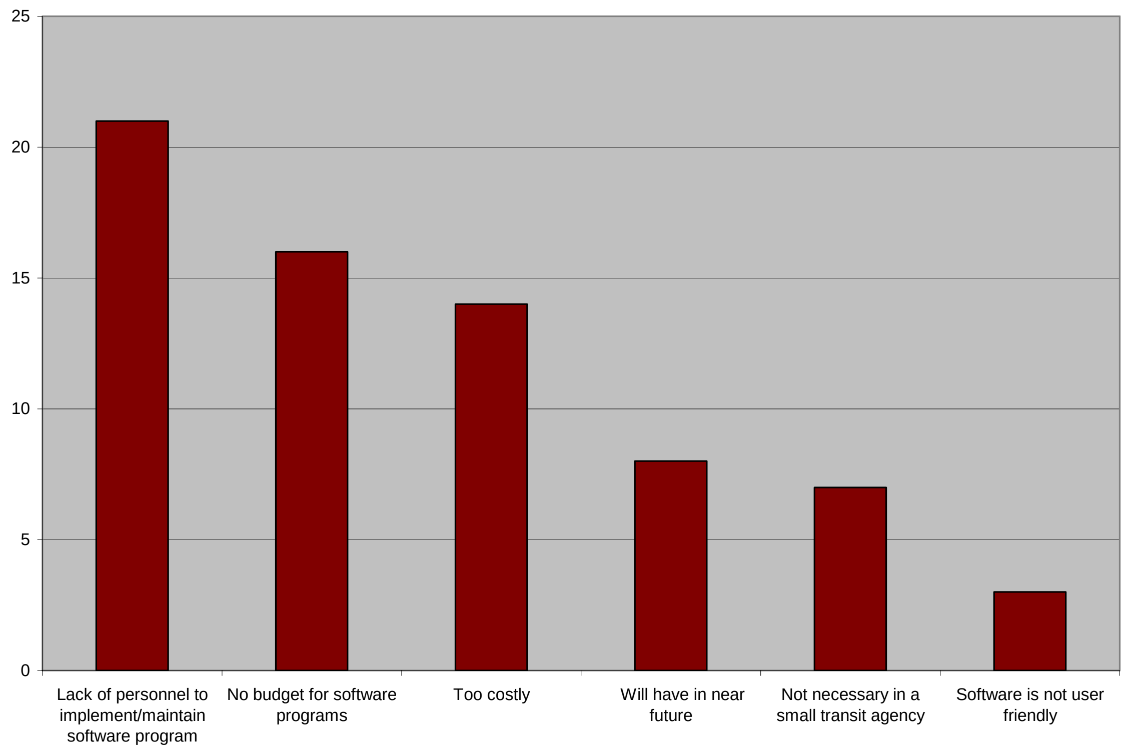
Over half (56%) of transit agencies reported to use GIS or Global Position System (GPS) to collect transit performance data. Of those who responded did not use the systems, a majority responded that the lack of personnel to run a GIS program or use GPS technology is the main reason for not using GIS or GPS to collect data. The next two reasons are both monetary. The agency either does not have a budget for software programs or the technologies are too costly for the agency. It should be noted that 8 of these agencies indicate that they will be using them soon. Table 13 and Figure 11 show these results.

TABLE 13: WHY GIS OR GPS ARE NOT USED TO COLLECT DATA

REASON FOR NO GIS/GPS TO COLLECT DATA	COUNT	PERCENT	RANK
Lack of personnel to implement/maintain software program	21	45.65%	1
No budget for software programs	16	34.78%	2
Too costly	14	30.43%	3
Others			
Will have in near future	8	17.39%	4
Not necessary in a small transit agency	7	15.22%	5
Software is not user friendly	3	6.52%	6

**Question: If no, why do you not use GIS and/or GPS to collect data? (Check all that apply)*

FIGURE 11: WHY GIS OR GPS ARE NOT USED TO COLLECT DATA



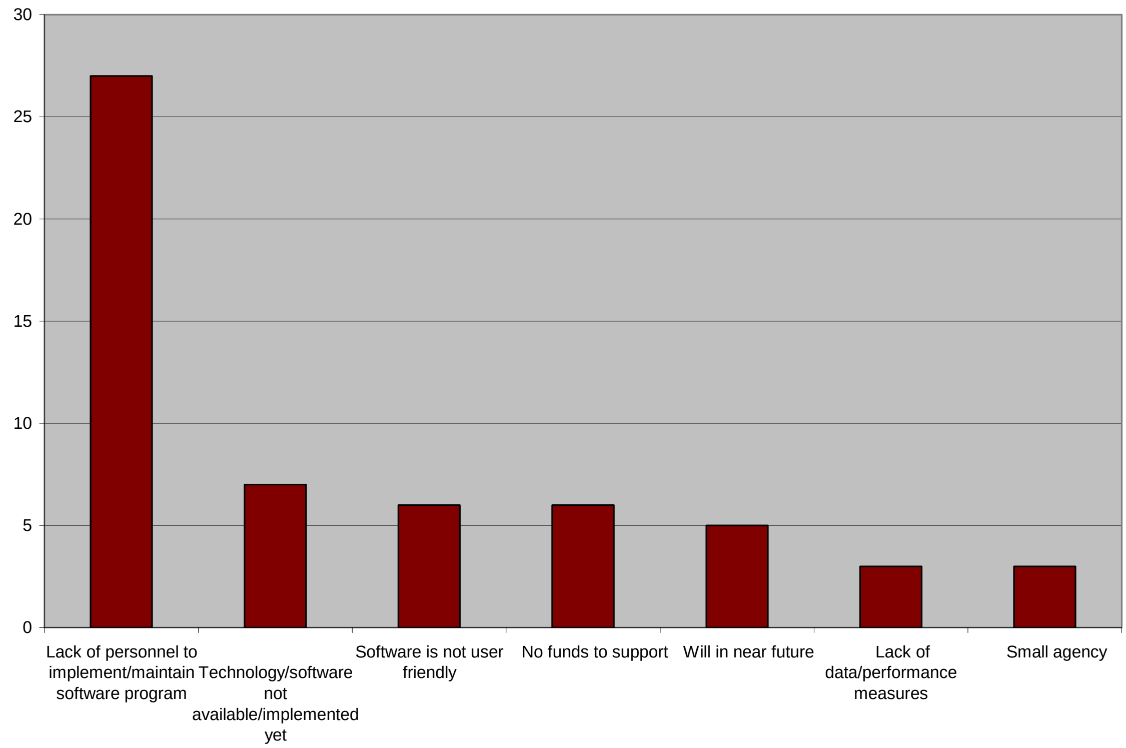
Among all respondents, more than half (57%) reported that they did not use GIS to analyze or report transit performance data. The 59 who did not use GIS for analysis or reporting were then asked why not. These results are shown in Table 14 and Figure 12. Lack of personnel was again cited by about half of the respondents as a barrier.

TABLE 14: WHY GIS IS NOT USED TO ANALYZE OR REPORT DATA

REASON FOR NOT USING GIS TO ANALYZE/REPORT DATA	COUNT	PERCENT	RANK
Lack of personnel to implement/maintain software program	27	45.76%	1
Others			
Technology/software not available/implemented yet	7	11.86%	2
Software is not user friendly	6	10.17%	3
Others			
No funds to support	6	10.17%	3
Will in near future	5	8.47%	5
Lack of data/performance measures	3	5.08%	6
Small agency	3	5.08%	6

**Question: If no, why do you not use GIS to analyze or report performance data? (Check all that apply)*

FIGURE 12: WHY GIS IS NOT USED TO ANALYZE OR REPORT DATA



The survey also asked the importance of GIS in evaluating transit performance at the system level and the route level. The respondents who use GIS indicated that the technology is more important at the route or route segment analysis level than at the system level. Table 15 shows these results.

TABLE 15: IMPORTANCE OF GIS AT DIFFERENT LEVELS

LEVEL	1	2	3	4	5	AVERAGE
System	3	2	12	16	11	3.68
Route/Route Segment	1	1	7	13	21	4.21

**Question: How important is GIS in measuring performance at the following levels?*
**Note: There was 1 no-score for Route/Route Segment which was not included in calculating the average score of the Route/Route Segment.*

Summary of Part II: Part II of the survey indicated that GIS has been generally recognized as an efficient and effective way to integrate, analyze and report transit performance, particularly at the route or route segment level. It is particularly useful for evaluating social accessibility measures. The survey revealed that about two-thirds of the respondents have GIS available in their agencies, but only a little over half (56%) of transit agencies have used GIS in analyzing and reporting transit performance. It signifies that there are some transit agencies that have GIS software but do not use it for data analysis and reporting.

The major reasons for not having GIS or not using GIS software are the lack of technical personnel and the lack of budget. Except for a few small transit agencies, most agencies seem to recognize the importance of using GIS and GPS technologies for collecting, analyzing, and reporting transit performance data. But many of them lack the technical personnel and budget to effectively use the technology for these purposes.

Use of Other Technologies for Transit Performance Measurement

The use of other technologies was also explored with the survey. This was done since other technologies besides GIS can be used to evaluate transit performance. The two major technologies that were asked about in Part III were Automatic Vehicle Locator Systems (AVL) and Automatic Passenger Counters (APC). These technologies relate to the questions from Part I that dealt with the sources of performance data and how it is collected. Responses in Part I indicated that past collection methods were done manually and/or with less advanced technologies. In Part III we focused more on the use of technologies to improve and measure performance.

Close to half of the survey respondents (43.3 %) have an AVL system available. Among those who have AVL technology, over three-fourths reported that AVL has improved on-time performance.

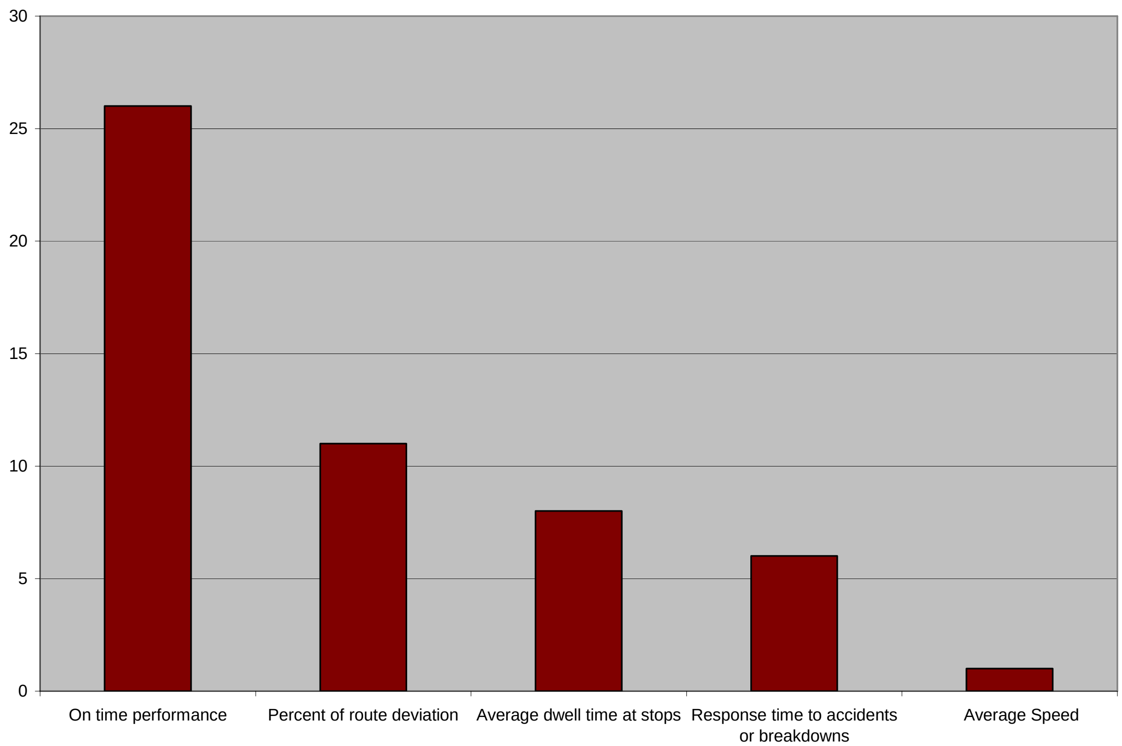
Among all survey respondents, regardless of whether they have AVL or not, almost all of them (98%) responded that AVL can be used to measure transit performance. Those who felt it could were then asked if they currently use AVL for that purpose. Surprisingly, almost three-fourths of respondents said they did not currently use AVL to measure transit performance. Even for those 45 agencies that have AVL, only 27 of them currently use AVL data to measure transit performance. The 27 agencies that have AVL were then asked what performance indicators were measured using AVL data. Nearly all (96%) of the respondents replied that AVL was used to produce on-time performance. About 40% said they used AVL to determine route deviation. Other indicators that could be derived from AVL include average dwell time at stops and response time to accidents or breakdowns, as demonstrated in Table 16 and Figure 13.

TABLE 16: AVL-PRODUCED PERFORMANCE INDICATORS

PERFORMANCE INDICATORS FROM AVL	COUNT	PERCENT	RANK
On time performance	26	96.30%	1
Percent of route deviation	11	40.74%	2
Average dwell time at stops	8	29.63%	3
Response time to accidents or breakdowns	6	22.22%	4
Others			
Average Speed	1	3.70%	5

**Question: If yes, what performance indicators does AVL produce? (Check all that apply)*

FIGURE 13: AVL-PRODUCED PERFORMANCE INDICATORS



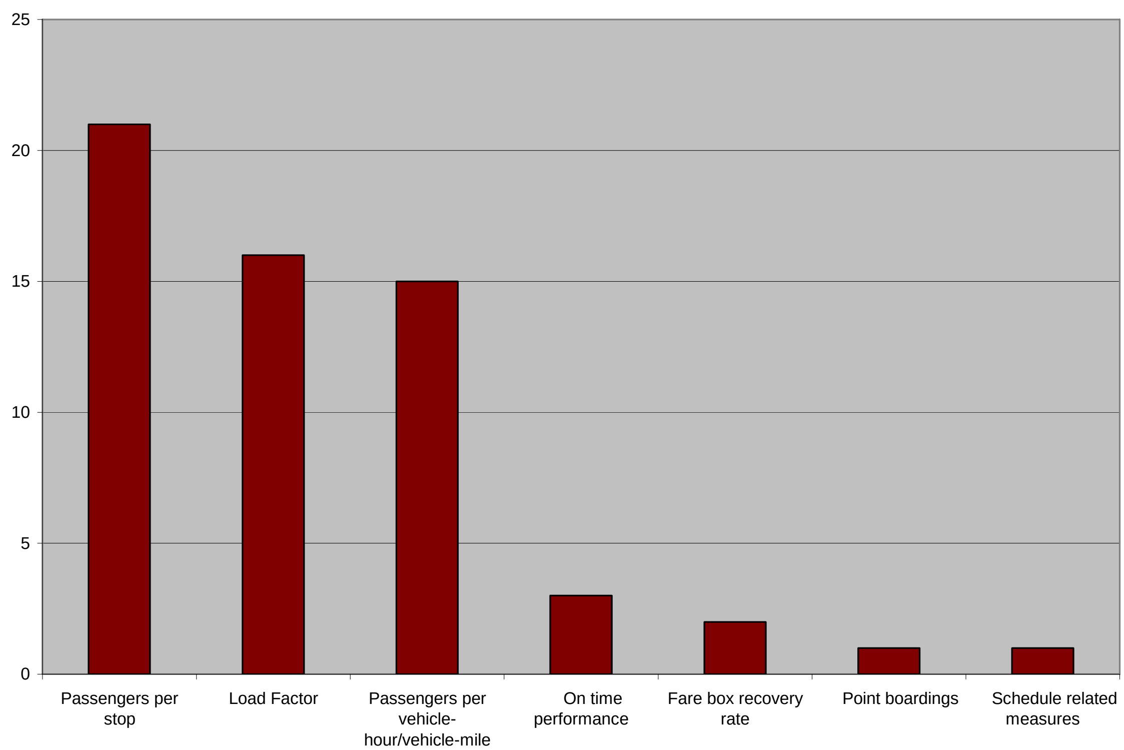
The survey also asked if Automatic Passenger Counters, APCs, can be used to measure transit performance. A vast majority of agencies (93%) believe it can be. Two follow-up questions were then asked. The first was of those who said yes and asked if they currently use APC for the purpose of transit performance measurement. It was found that almost two-thirds currently do not use APC for assessing their performance. The 32 agencies which do currently use APC for transit performance assessment were asked what performance indicators APC has produced. The most commonly used performance indicators derived from APC include passengers per stop (66%), load factors (50%), and passengers per vehicle mile or hour (47%). These indicators are found in Table 17 as well as in Figure 14.

TABLE 17: APC-PRODUCED PERFORMANCE INDICATORS

PERFORMANCE INDICATORS FROM APC	COUNT	PERCENT	RANK
Passengers per stop	21	65.63%	1
Load Factor	16	50.00%	2
Passengers per vehicle-hour/vehicle-mile	15	46.88%	3
Others			
On time performance	3	9.38%	4
Fare box recovery rate	2	6.25%	5
Others			
Point boardings	1	3.13%	6
Schedule related measures	1	3.13%	6

**Question: If yes, what performance indicators does APC produce? (Check all that apply)*

FIGURE 14: APC-PRODUCED PERFORMANCE INDICATORS



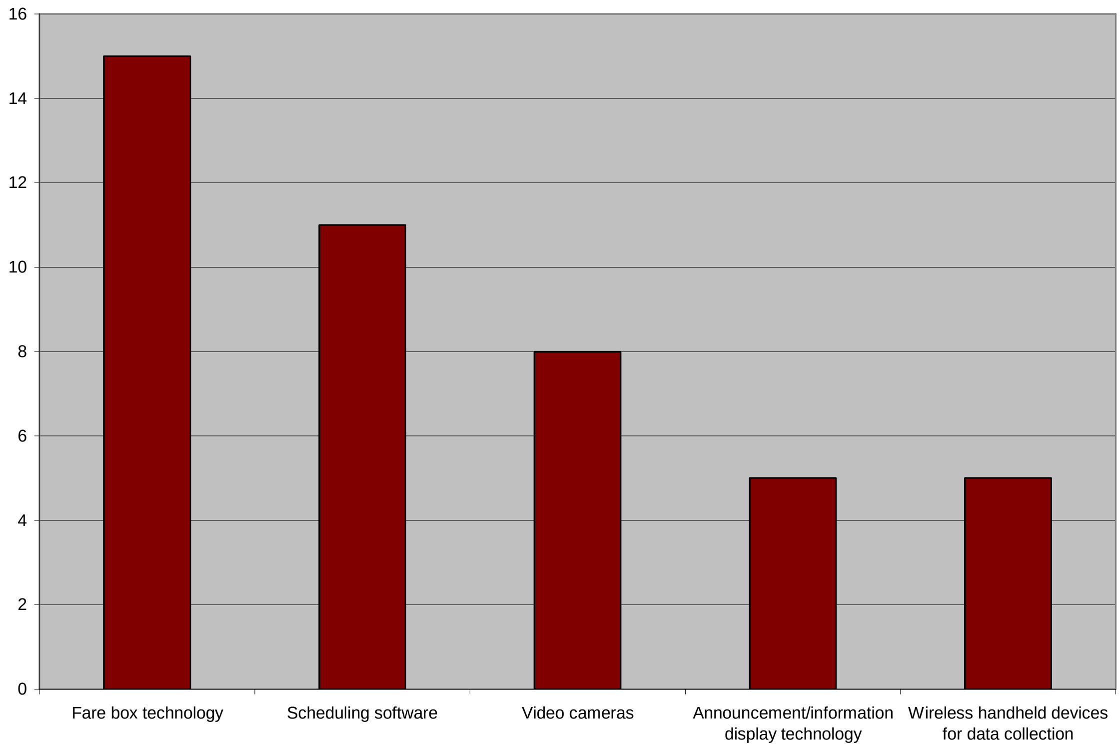
The final question of the survey asked the agencies if they used other technologies and, if so, what those technologies were. Less than half of the agencies use other technologies (44%). Out of those who do use other technologies, the top five technologies as shown in Table 18 and Figure 15, are farebox technology, scheduling software, video cameras, stop problems have been encountered in collecting performance data announcements and hand-held data collectors.

TABLE 18: PERFORMANCE INDICATORS FROM OTHER TECHNOLOGIES

TECHNOLOGY	TOTAL	RANK
Fare box technology	15	1
Scheduling software	11	2
Video cameras	8	3
Announcement/information display technology	5	4
Wireless handheld devices for data collection	5	4

**Question: If so, what are these other technologies? (List all others)*

FIGURE 15: PERFORMANCE INDICATORS FROM OTHER TECHNOLOGIES



Summary of Part III: The third part of the survey focused on AVL and APC technologies. AVL and APC technologies were not extensively used by the respondents. Only one-third of transit agencies have APC and 43.3% have AVL technologies. For those that have AVL, nearly all of them reported that AVL had improved on-time performance. While nearly all agencies felt that AVL could be used to measure performance, only 27 of those 45 who have AVL technology currently use AVL data to measure transit performance.

The results for the APC questions were quite similar to those of the AVL questions. Most agencies do not have APC, but of those who do, nearly all feel it has provided useful information to measure transit performance. The agencies indicated that APC could definitely be used to measure performance but, once again, most agencies do not currently use APC for measuring performance. This indicates a possible area of improvement for transit agencies if more agencies could find a way to take advantage of the two technologies.

The survey question did not ask why the agencies that have AVL and APC do not use these technologies to evaluate transit performance. So a follow-up telephone interview was conducted. We found that the most important reasons are the lack of standard and easy to use procedures, the lack of user friendly software, and the lack of technical personnel.

Does Agency Size Make Any Difference?

One would suspect that responses to the survey would vary by size of the transit agencies. Does the agency's size affect what technologies are used by the agency? Does the agency's size affect what performance measures are used by the agency? These are two important questions when discussing transit performance assessment and they can be addressed using statistical methods.

To find the answers to these questions, we used the agency information at the National Transit Database (NTD) to determine the agency size. The measure of agency size used was vehicles operated in maximum service (VOMS). This measure, according to the NTD definition, is the "revenue vehicle count taken during a transit agency's maximum season of the year, on the day of the week that this maximum occurs". It is a useful measure of agency size because it reflects the level of operation of an agency. Using VOMS, we split the responding agencies into three groups; small, medium, and large. Tables 19 and 20 and Figures 16a-c were then created by running cross-tabulations between each technology question and the agency size classifications. Table 19 contains the count data which show how many respondents in each size category responded in each way to each question while Figures 16a-c represent these data for each technology; GIS, AVL, and APC. Table 20 shows measures of association along with their respective significance levels.

The measures of association tested, shown in Table 20, indicate that the use of technology is closely related with the size of transit agencies. The general pattern seems to be the larger the transit agency size, the more likely they are to use technologies to measure transit performance and for other purposes. For example, larger agencies are more likely to have GIS, AVL and APC technology, and the more likely it is to use GIS or GPS in performance measurement. But, in terms of believing AVL and APC can improve useful information and can be used to measure transit performance, there is no difference in terms of agency size; all believe they can.

TABLE 19: AGENCY SIZE AND TECHNOLOGY

Question topic	Response	Agency Size		
		Small	Medium	Large
GIS accessible	NO	11	9	2
	YES	18	19	25
GIS/GPS used to collect data	NO	15	9	6
	YES	14	19	21
GIS used to analyze/report performance data	NO	22	13	7
	YES	7	15	19
AVL possessed	NO	21	17	6
	YES	8	11	20
AVL has improved on-time performance	NO	3	0	6
	YES	5	10	13
AVL can be used to measure transit performance	NO	0	2	0
	YES	28	25	26
AVL is currently used to measure transit performance	NO	23	20	12
	YES	4	5	14
APC possessed	NO	25	17	7
	YES	4	11	19
APC has produced useful information	NO	0	0	2
	YES	4	10	16
APC can be used to measure transit performance	NO	4	0	0
	YES	22	29	27
APC is currently used to measure transit performance	NO	19	17	8
	YES	3	11	16

FIGURE 16a: AGENCY SIZE AND TECHNOLOGY - GIS

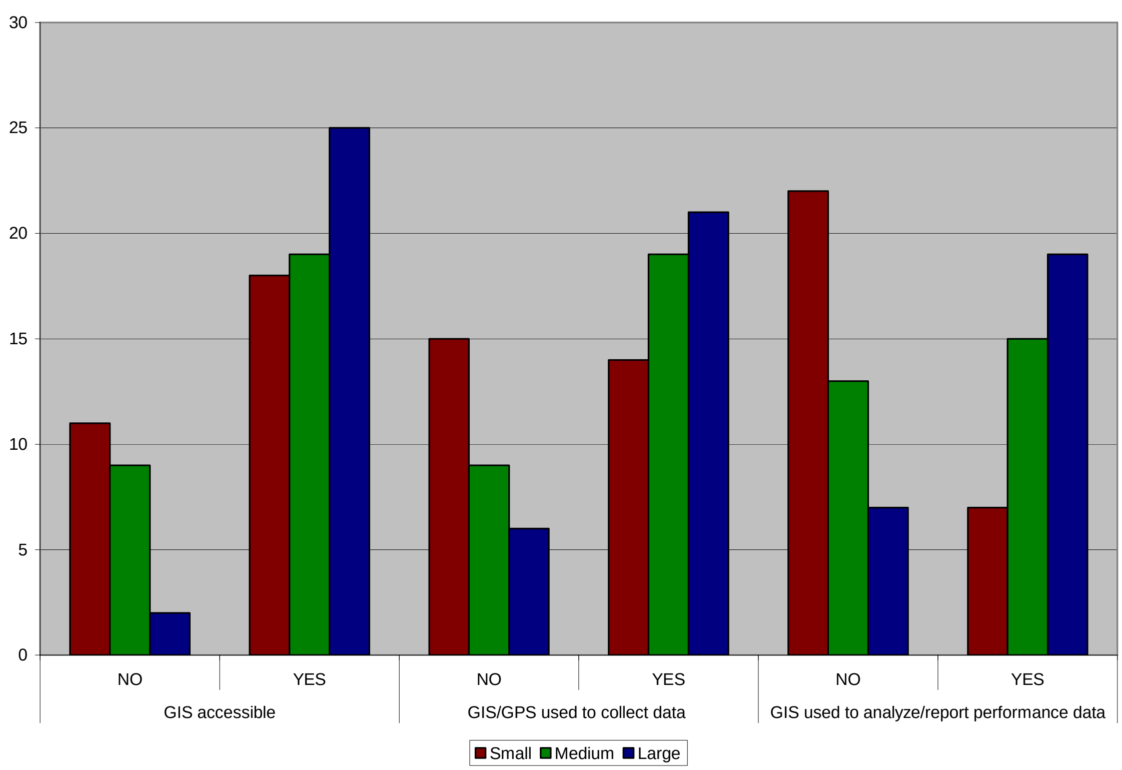


FIGURE 16b: AGENCY SIZE AND TECHNOLOGY - AVL

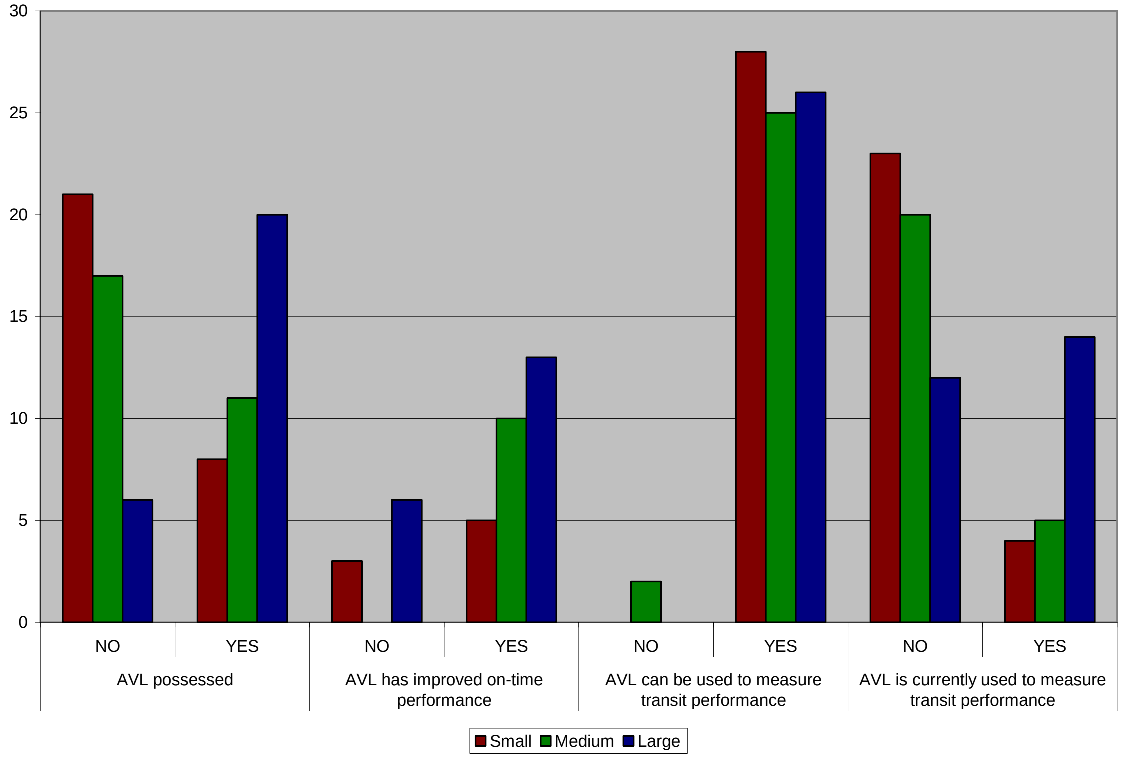


FIGURE 16c: AGENCY SIZE AND TECHNOLOGY - APC

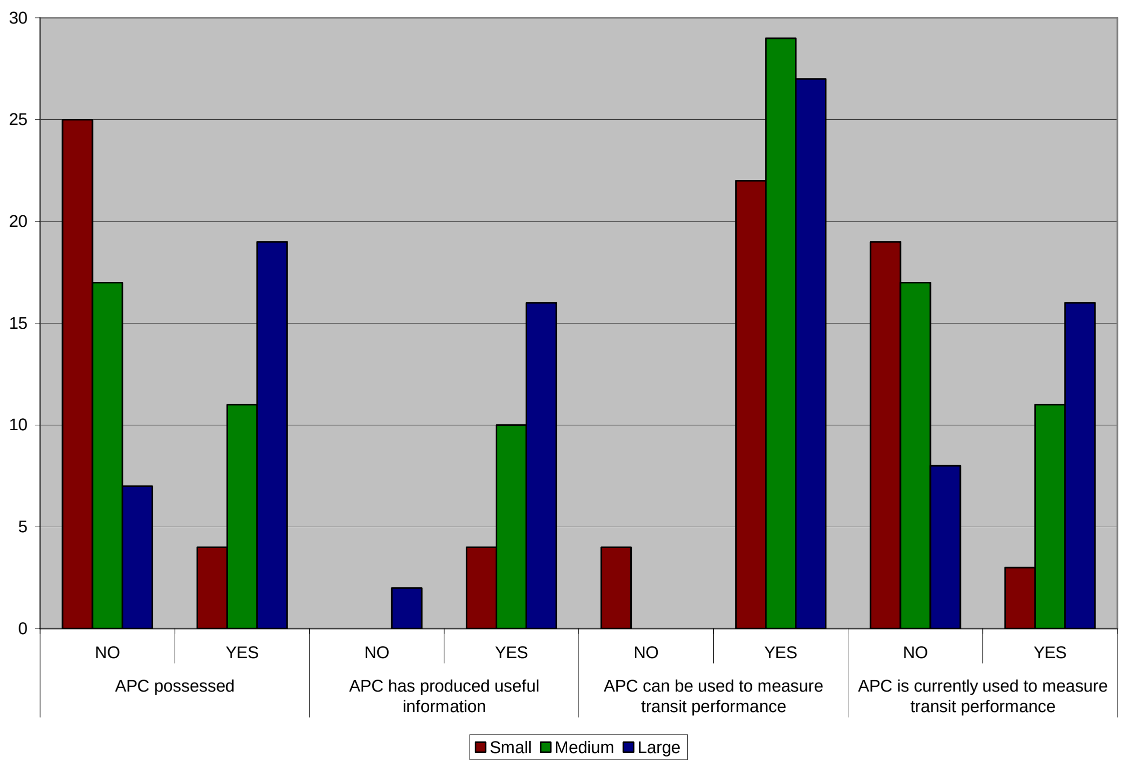


TABLE 20: AGENCY SIZE AND TECHNOLOGY ASSOCIATION

	Measure of Association Relating to Agency Size				
Question topic	Chi-square	Significance	Gamma	Kendall's tau-c	Significance
GIS accessible	7.51	0.023	0.501	0.268	0.004
GIS/GPS used to collect data	5.53	0.063	0.418	0.264	0.016
GIS used to analyze/report performance data	13.43	0.001	0.605	0.435	0.000
AVL possessed	14.40	0.001	0.597	0.430	0.000
AVL has improved on-time performance	4.51	0.105	-0.132	-0.061	0.714
AVL can be used to measure transit performance	4.10	0.129	-0.037	-0.002	0.789
AVL is currently used to measure transit performance	11.30	0.004	0.585	0.348	0.001
APC possessed	19.97	0.000	0.722	0.523	0.000
APC has produced useful information	1.66	0.436	-1.000	-0.109	0.134
APC can be used to measure transit performance	9.06	0.011	1.000	0.133	0.033
APC is currently used to measure transit performance	13.42	0.001	0.656	0.454	0.000

We also wanted to find out if agencies of different size use different performance measures. Tables 21 and 22, along with Figure 17, display the results of association tests, comparing agency size with different performance measures. The six performance measures chosen were the six most popular measures from the survey. The results show that except for on-time performance, there is not much difference in performance measures used at different sized agencies. On-time performance, however, was found to be associated with the size of agency. Large agencies seem to be more concerned about using on-time performance as a measure, while smaller agencies are less concerned with this measure. This may be because on-time performance in small agencies is not as big a problem as in large agencies.

TABLE 21: AGENCY SIZE AND PERFORMANCE MEASURES

		Agency Size		
Performance Measure	Response	Small	Medium	Large
Ridership	NO	7	6	3
	YES	15	22	24
Cost	NO	9	9	14
	YES	13	19	13
Farebox Recovery Rate	NO	11	14	15
	YES	11	14	12
On-time Performance	NO	15	16	9
	YES	7	12	18
Customer Satisfaction	NO	11	17	19
	YES	11	11	8
Accidents	NO	9	20	13
	YES	13	8	14

FIGURE 17: AGENCY SIZE AND PERFORMANCE MEASURES

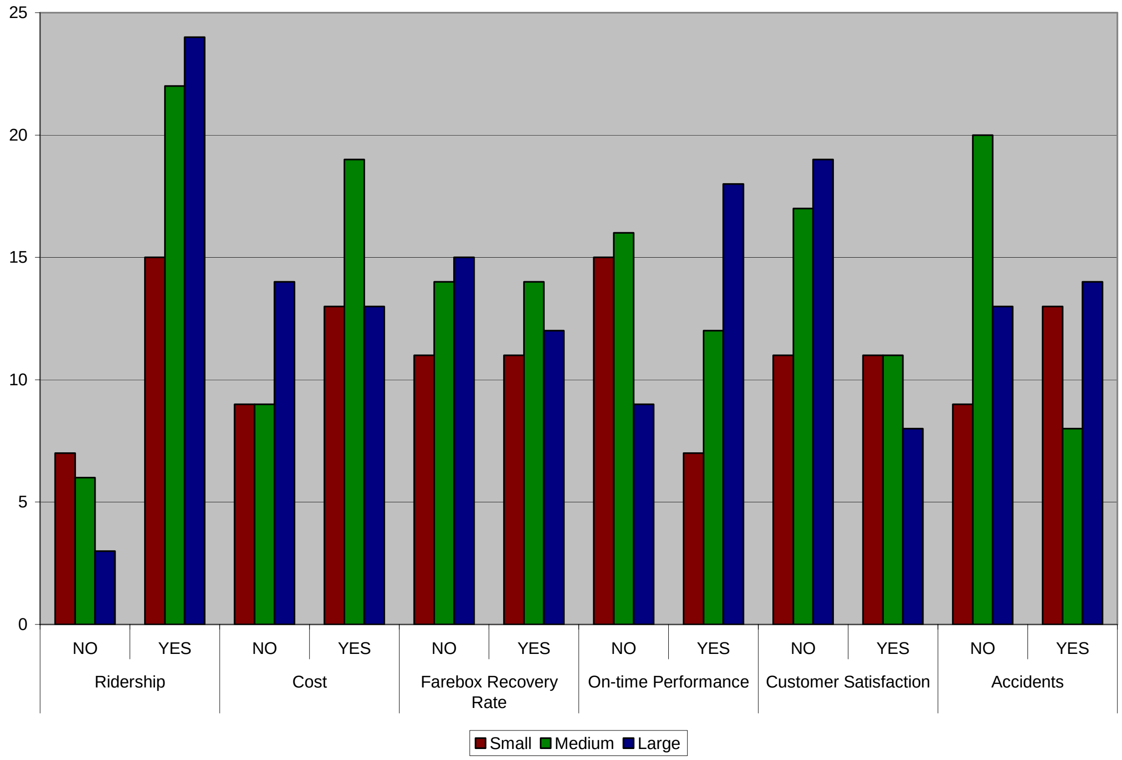


TABLE 22: AGENCY SIZE AND PERFORMANCE MEASURES ASSOCIATION

	Measure of Association Relating to Agency Size				
Performance Measure	Chi-square	Significance	Gamma	Kendall's tau-c	Significance
Ridership	3.169	0.205	0.397	0.179	0.070
Cost	2.204	0.332	-0.165	-0.108	0.384
Farebox Recovery Rate	0.217	0.897	-0.076	-0.051	0.682
On-time Performance	6.373	0.041	0.446	0.307	0.009
Customer Satisfaction	2.117	0.347	-0.274	-0.175	0.140
Accidents	5.315	0.070	-0.054	-0.037	0.772

SUMMARY AND CONCLUSIONS

The goal of this project was to determine the state of practice of transit agencies in the use of performance measures and advanced technologies to enhance transit management and performance measurement. TCRP *Report 88* asserted that agencies measure performance for three main reasons. The first is that it is required to a certain extent for every agency. Second, it is useful for a transit agency to assess its performance in order to maintain and improve their service. And third, accurate information is needed to present to decision-making bodies to ensure proper service as well as to the public so that people know if their transit system is valuable.

The results of our survey reinforce these reasons, but in a different order. Of the agencies responding to the survey, nearly all of them utilize performance measures to assess their systems and of those, almost all of them find the measures are important primarily because they help to maintain and improve the quality of the services that they provide. Reporting to funding agencies and decision-making bodies was also important but to a lesser degree in spite of the fact that they are required. Of a lesser importance was the use of indicators for social purposes, to report to the public and to relate to community goals. This reflects the current status of performance measurement, that is, it is more important to measure transit performance for business purposes rather than for public service or social purposes.

TCRP 88 also includes an extensive list of performance measures that can be used. The report acknowledges that different agencies may have different needs for their performance measures. In our survey, ridership and cost measures were found to be the two most popular measures but there was a wide range of specific measures that agencies found important and used. This was the case for all transit agencies, regardless of size. Most agencies have had difficulty with collecting the data for the various performance measures. This is consistent with Bertini and El-Geneidy's (2002) finding that collecting comprehensive performance data has been difficult and expensive. Agencies have had to rely on measures that are incomplete or aggregated, which limits their usefulness. It is interesting to see, however, although most transit agencies still rely on traditional methods to collect performance data, there is some progress in shifting to more sophisticated technology-oriented methods.

The advancement and wide implementation of technologies for transit services provides advanced tools to not only evaluate traditional transit performance at the system level but also create new transit performance (e.g., social measures) at the route, route segment and even stop level. However, the results of the survey revealed a distinct gap between agencies believing the technologies are useful and agencies actually implementing them. For example, GIS is available to about two-thirds but less than half use it to integrate, analyze or report performance data. Similarly, although AVL can provide rich data for performance measurement at the fine-grain level, and transit systems consider AVL a great source of data for performance evaluation, only 60% of those who have AVL actually use it. The major barriers seem to be the lack of well-defined procedures and methods of measuring performance, the lack of well-trained technical personnel, and the lack of budget.

The expansion of advanced technologies like GIS, AVL and APC provide great potential to improve the efficiency of evaluating transit performance, and to create more accurate and more timely (even real-time) transit performance measures. But these hurdles have to be overcome. Procedures that are less technically complex should be provided to transit agencies in order to make full use of modern technologies. Technical training and funding are critically needed to support transit agencies, particularly small transit agencies to produce better transit performance measure to improve transit services.

PART II:
CASE STUDY

CASE STUDY: USE GIS TO ANALYZE TRANSIT PERFORMANCE

This section will illustrate the step by step process used to create a Geographic Information System (GIS) to evaluate the performance of a transit agency. Once completed, the GIS will provide the ability to measure a transit system's performance at the system level as well as at the route level. To create a GIS an off-the-shelf GIS program is needed to perform the necessary functions and display your results. This case study will use ArcGIS 9.0 to demonstrate the creation of a specialized GIS. The guide can be applied to other GIS programs but there may be slight differences in the steps.

GIS Data for Performance Evaluation

Specific data are necessary for transit performance measurement. These data can come from a number of sources. First, there are data collected by an agency in house. These data, as the TCRP 88 report states, "can be calculated from information an agency would normally have on hand" (p.130). Examples of this type of data are schedule data, maintenance records, financial data, fleet data, and so on. Another source is the National Transit Database (NTD), to which many agencies are required to submit information. This database includes service area characteristics, labor hours, cost data, fleet information, amount of service provided, amount of service consumed, and many others. TCRP 88 warns that, although it is a good source to "compare measures across agencies", the NTD may have inconsistencies from the reporting of different agencies.

Other agencies may have demographic data, traffic data, and GIS data that they can provide. Demographic data include population and household data, usually from the U.S. Census Bureau or local planning authorities, and employment data, also from planning organizations or state employment departments. Traffic data, including "daily traffic volumes, traffic speeds, sidewalk inventories, traffic signal timing information, and the number of lanes provided on streets" (132), can be found at local public works departments or state departments of transportation. GIS data are the demographic or traffic data with spatial location information that can be analyzed using GIS software.

The difficulty of collecting data in the past has been that it has required a great deal of labor which leads to a small number of trips being sampled because of the high costs. The alternative to this is automated or semi-automated data collection such as the use of Automatic Vehicle Location (AVL) technology instead of manual collection. AVL equipment, according to TCRP 88, has two main functions. They are "to track the real-time location of AVL-equipped buses" and "to collect and store data about bus arrival and departure times" (136). Automatic Passenger Counters (APC) are another form of technology to aid in data collection. This can save on labor costs as well as increase the availability of ridership data at the system, route and stop level. Data collected with this method, according to TCRP 88, include "stop, route and system-level ridership; maximum passenger loads and their locations; passenger miles; how long standing loads occur during a trip; and how often loads exceed a pre-determined level" (138).

In research by Beimborn, Greenwald, and Xia at UW-Milwaukee, a number of data sets related to transit performance are examined. Their work: "Transit Accessibility and Connectivity Impacts on Transit Choice and Captivity", describes the implementation of a "Geographic Model for Bus Service Planning and Marketing". Four data sets are required to integrate into the model. The first set is geographic data which consists of a digital map of census tracts by latitude and longitude. The second set is transit service data which is a network of bus routes and frequencies. Third is residential data, consisting of details on households and residents. The fourth and final set is worker data describing workers in each tract. They also separated trip types into three categories. The first being work trips of residents in the tract. Second, there are work trips of workers in the tract. Third, there are non-work trips in the tract.

GIS Analysis for Performance Measures -- A Case Study of the Waukesha Metro Transit System

Details of the process and data sources are given below and should be consulted if the process is to be repeated in another location.

Step 1: Gather the Necessary Data

The first data that are needed are vector data for the area the agency serves. Vector data describe individual geographic features which can be in the forms of points, lines and polygon objects which are defined by mathematical formulas. The most important points in a transit GIS are bus stops. The lines are the existing bus routes. The polygons will be the representations of different areas, such as census tracts and block groups. The next data that will be incorporated into the GIS are demographic data for residents which are collected by the U.S. Census Bureau. Details of data needs and steps to produce results are given in the following tables.

Table 23: Data Needs for a Transit GIS:
General data • Point file that represents locations of landmarks • Point file that represents locations of bus stops • Line file that represents the network of bus routes • Line file that represents the network of streets • Polygon file that represents the location of geographic areas defining census block groups • U.S. Census Bureau Block Group Data that includes demographic data for residents within each block group • Orthophotos which are aerial photos that have been geometrically corrected for relief displacement of the topography. They have all the image qualities of a photo, but have all the geometric qualities of a map.
FTA Bus GIS Database
• A GIS line database of the streets of the county or counties where the service is located from Bureau of the Census 1992 Enhanced TIGER files
• A condensed file of the TIGER-based street network that takes up less data storage and provides quicker access and display
• A GIS network built from the county street database
• A GIS route system of the bus routes, built from selected TIGER street segments as indicated on the transit agencies route maps and schedules
• All of the above GIS data products are condensed into a self-executable "zip file" for archiving and data transfer
FTA Level of Service (LOS) Information
• Days (of the week) of service
• Start and end time of weekday service
• Frequency of service for
• Morning peak
• Mid-day peak
• Afternoon peak
• Evening
• Information on Saturday and Sunday service, if available
• Information on accessibility of the route (e.g. dedicated lift equipped buses for all or part of the day)
• Description of fares, if available

Table 24: Steps in Assembly of National Transit Database Data
Go to FTA website: http://www.fta.dot.gov/ • Click “Transit Data and Info” which takes you to: http://www.fta.dot.gov/14512_ENG_HTML.htm • Click on “Transit Agency Financial & Operating Data Tables” which takes you to: http://www.fta.dot.gov/transit_data_info/national_transit_db/1082_611_ENG_HTML.htm • Click on “Transit Agency Financial & Operating Data Tables” again which takes you to: http://www.ntdprogram.com/NTD/NTDData.nsf/DataTableInformation?OpenForm&2001 • On the left side of the page Right Click “01tabxls.exe” and Click “Save Target As…” • Choose where to save the file and click “Save” • Once the download completes find where you saved the file and double-click it • Click “Run” • Choose the folder to Unzip to and click “Unzip” • After successful unzipping, find you agency’s row in each Microsoft Excel spreadsheet to locate your data • For an explanation of the tables follow the first four steps then: • Right Click “Data Tables for Individual Transit Agency Statistics” and Click “Save Target As…” • Choose where to save the file and click “Save” • Once the download completes find where you saved the file and double-click it to open it

Steps in Assembly of TIGER Data
• Topologically Integrated Geographic Encoding and Referencing (TIGER)
• TIGER files are from the U.S. Census Bureau
• Defines location/relationship of streets, rivers, railroads, etc. to each other and to numerous geographic entities which the Census Bureau uses
• Primary features are street segments with address ranges along them
• Found at: www.census.gov/geo/www/tiger
• To make use of TIGER/Line data (creation of maps, etc.), one must have mapping or GIS software that can import the data
• TIGER/Line does not include demographic statistics

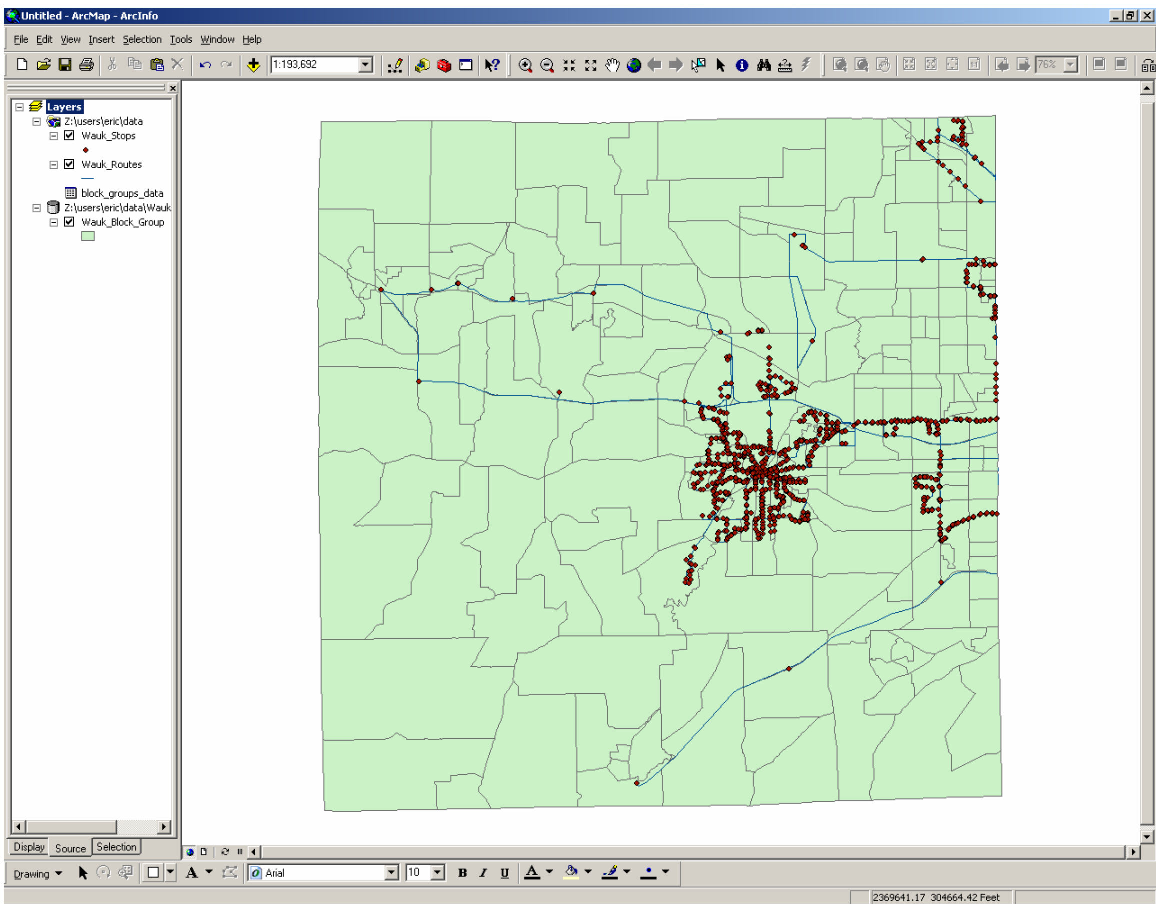
Step 2: Display Data Using GIS Programs

In this case study, ArcMap was used. The specific process is as follows: To begin, open ArcMap. When the opening ArcMap dialog box pops up make sure that 'A New Empty Map' is chosen. Then check the box at the bottom that says 'Immediately Add Data'. Click 'OK'. This will bring up the Add Data Dialog Box (you may also click the 'Add Data' button to bring up this dialog box). From here, navigate to where your vector data (the points, lines and polygons) are being stored (You may need to click the 'Connect to Folders' icon if you cannot navigate to your data from the original Add Data Dialog Box). Highlight all the necessary files using the Control or Shift keys and click 'Add'. The files should show up under 'Layers' to the left side of your map display and they should be visually present on the map display itself.

Next, repeat the above process to add your U.S. Census Block Group data. This data can be seen by clicking the 'Source' tab on the lower left portion of your screen.

At this point your screen should look similar to Figure 18:

FIGURE 18: LAYERS ADDED TO ARCMAP



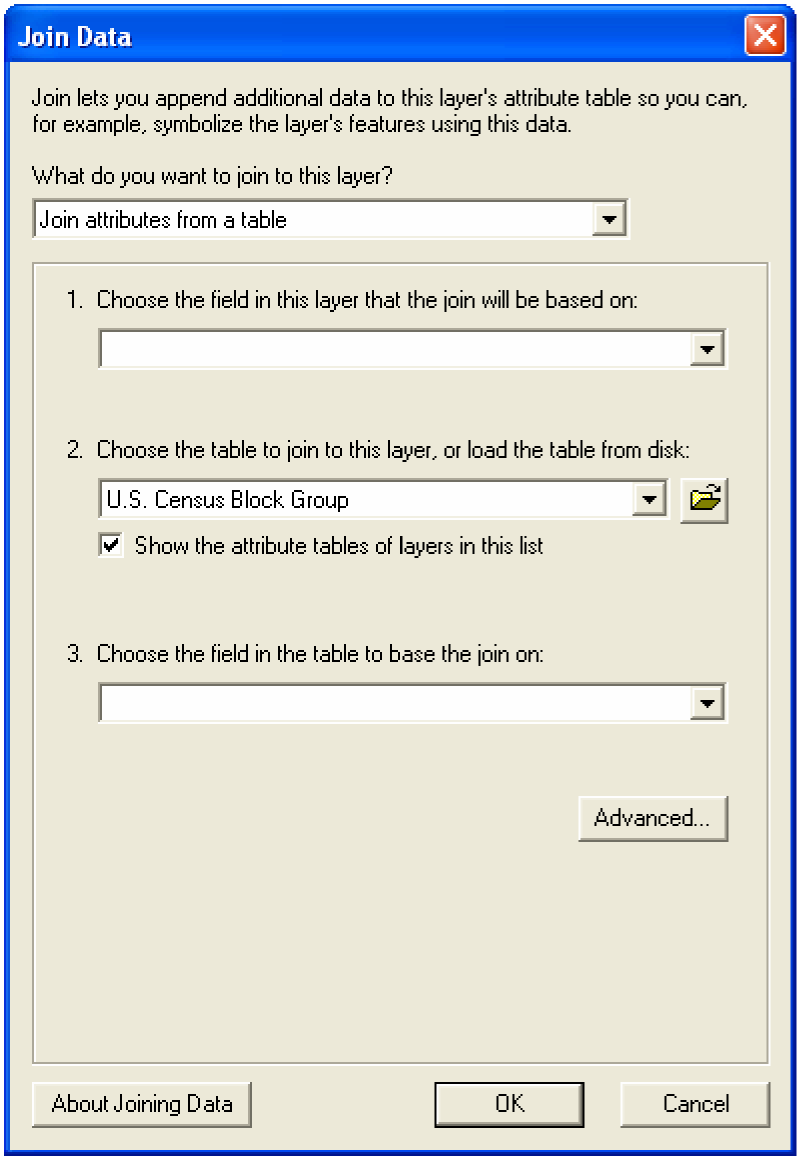
The map should be saved to the same location as the data that was added. This map file will have an .mxd extension.

For each layer there is an attribute table that has data associated with the layer. Right click on a layer and choose 'Open Attribute Table'. You can scroll up/down and left/right to see each 'Field' (column) and 'Record' (row). Do this for each of the layers to become familiar with the data represented within each layer.

Step 3: Join Tables

Data from the U.S. Census block group data table should be joined to the block groups polygon layer so that the data can be shown spatially. The data table and the polygon layer will need to have matching unique identifier fields in each of their respective attribute tables for this to work. This field will be the basis for joining the table to the layer. To join the tables right click on the polygon layer, select 'Joins and Relates', and select 'Join…'. This will load the 'Join Data' dialog box as shown in Figure 19. Under the first drop-down menu you want 'Join attributes from a table'. Next, choose the unique identifier field in the block group polygon layer that the join will be based on. Then select the Census block group data as the table to join. Finally, select the unique identifier field in the Census block group table as the field to join. Click OK. Your tables will now be joined. (If you receive a warning concerning indexing, click ok and continue: don't worry if you don't get that warning).

FIGURE 19: JOIN DATA DIALOG BOX

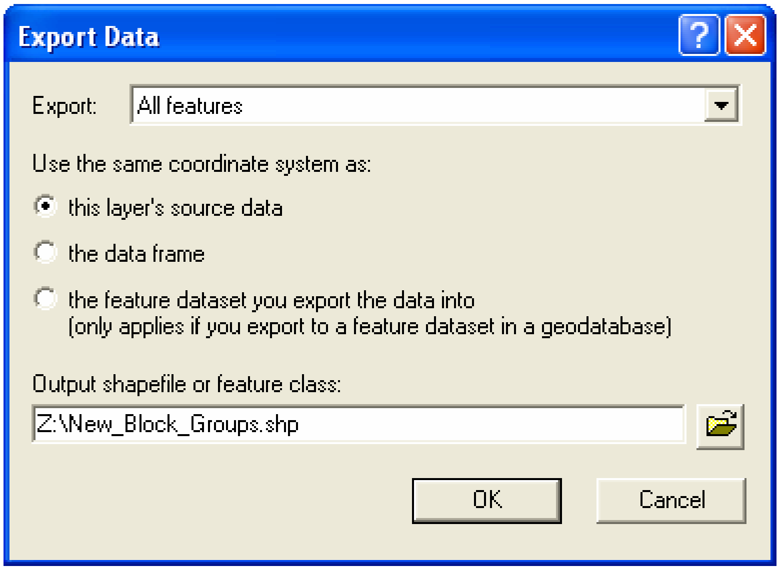


Open the new joined attribute table (which is under the block group polygon layer). It will contain all of the original attributes from the original attribute table, plus it now has all of the socio-demographic information from the Census block group data.

Step 4: Exporting Layer as New Feature Class

Next, this layer with all of its changes will be exported as a new feature class. This will make the join permanent. Until this is done, it is possible to remove the join which will return the block group polygon layer's table to its original state. Right click on your block group polygon layer, select 'Data', and then select 'Export Data'. Click the 'Browse' button (see Figure 20) to select where the feature class should be saved. Change the 'Save as Type' to 'Personal Geodatabase feature classes'. Change the name of the layer (I will use New_Block_Groups). Click 'Save', then click OK.

FIGURE 20: EXPORT DATA DIALOG BOX



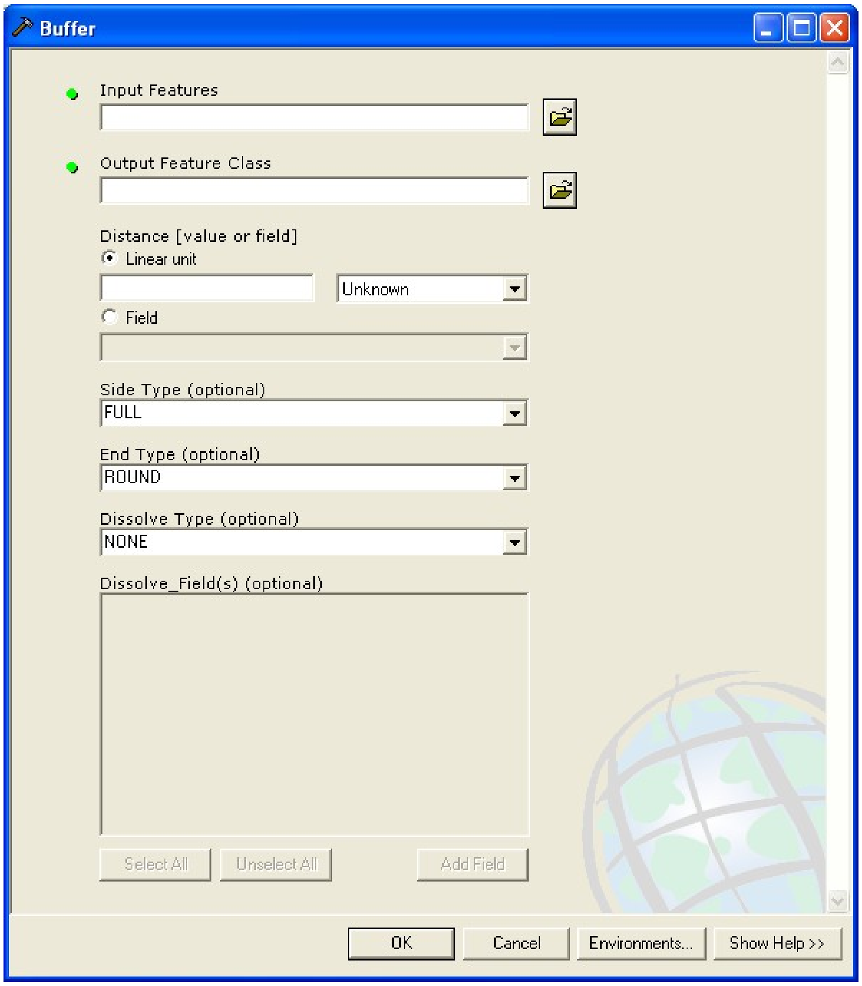
A popup message will ask if you want to add the new exported data to the map as a layer. Click ‘Yes’. Once the layer is added, right click on the old block group polygon layer and choose ‘Remove’.

Step 5: Buffering Bus Stops

The next step will be to locate the transit service catchment area by buffering all locations within a quarter mile of a bus stop. Buffering creates a polygon of an area in a new layer by drawing a constant distance around a feature (a point, a line, or a polygon). To buffer, open ArcToolbox. Click on ‘Analysis Tools’, then ‘Proximity’ and choose ‘Buffer’. This will launch the ‘Buffer’ dialog box shown below in Figure 21. When this box comes up you will first need to choose your bus stops layer as the ‘Input Features’ layer. This is the layer that will be buffered. Then choose the location for saving the buffer layer to by clicking the ‘Browse’ button and navigating to the folder where the files and layers are saved. Name the layer Stops_Buffer. Under ‘Distance’ type in .25 for ‘Linear unit’ and choose ‘Miles’ from the drop-down menu. This will make the buffer a quarter mile around each stop. Finally, for ‘Dissolve Type’ choose ‘ALL’ to dissolve all of the overlapping boundaries. Click ‘OK’ to begin the buffering process.

NOTE: The time period required for the buffering process to complete depends on many factors such as computer speed and number of stops so it may take a few minutes.

FIGURE 21: BUFFER DIALOG BOX



Once the process has concluded the transit service catchment area represented by the polygons of the stops buffer layer can be seen.

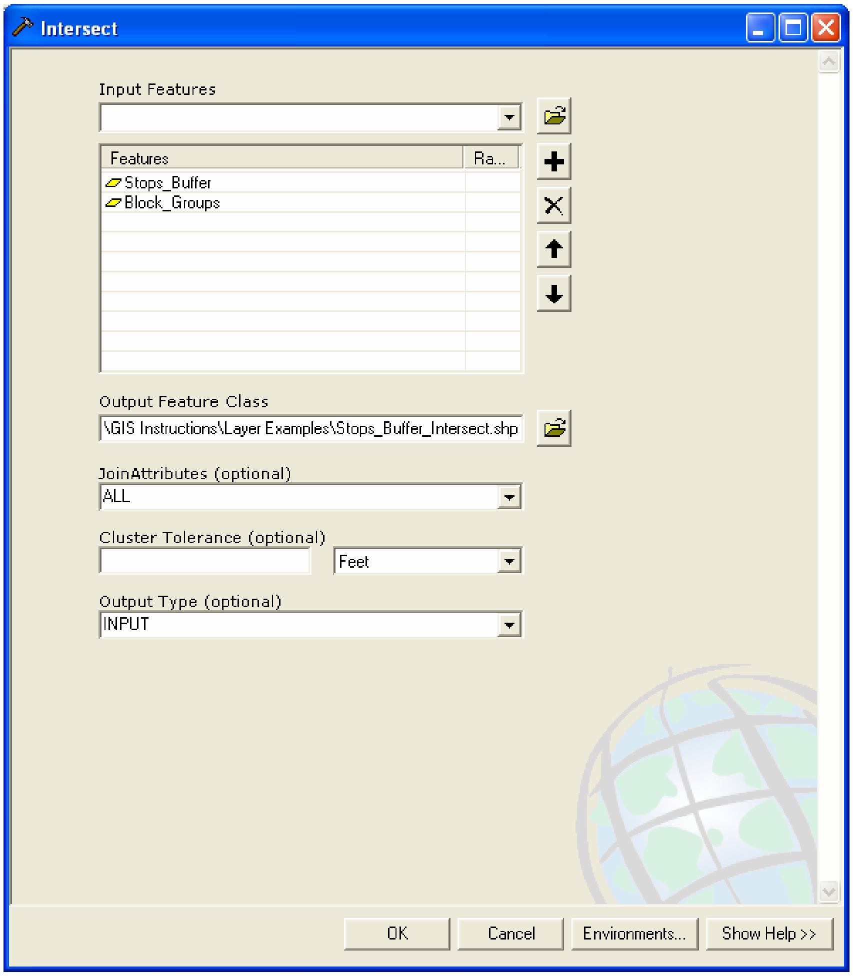
Step 6: Overlaying Bus Stops Buffer with Census Block Group Data

In order to be able to relate socio-demographic information to the transit service catchment area, you must overlay the stops buffer layer with the new block group polygon layer. Overlays identify the overlaps between features in two (or more) layers and create a new dataset based on where the overlap occurs. There are two basic types of overlay: Union and Intersect. A Union will create a new layer with all features from the two layers whether or not they are overlapped. For example, if portions of two polygons overlap, it will create a new feature where there is overlap, and retain all areas from the two layers that do not overlap. In an "Intersect" operation, only the areas that overlap will be preserved.

For this procedure Intersect will be used. In Arc Toolbox, select 'Analysis Tools', select 'Overlay', then 'Intersect'. For 'Input Features' select both the Stops_Buffer layer and the block group polygon layer. Change the name of the 'Output Feature Class' to 'Stops_Buffer_Intersect'. Select the defaults for 'Join Attributes' and 'Cluster Tolerance'.

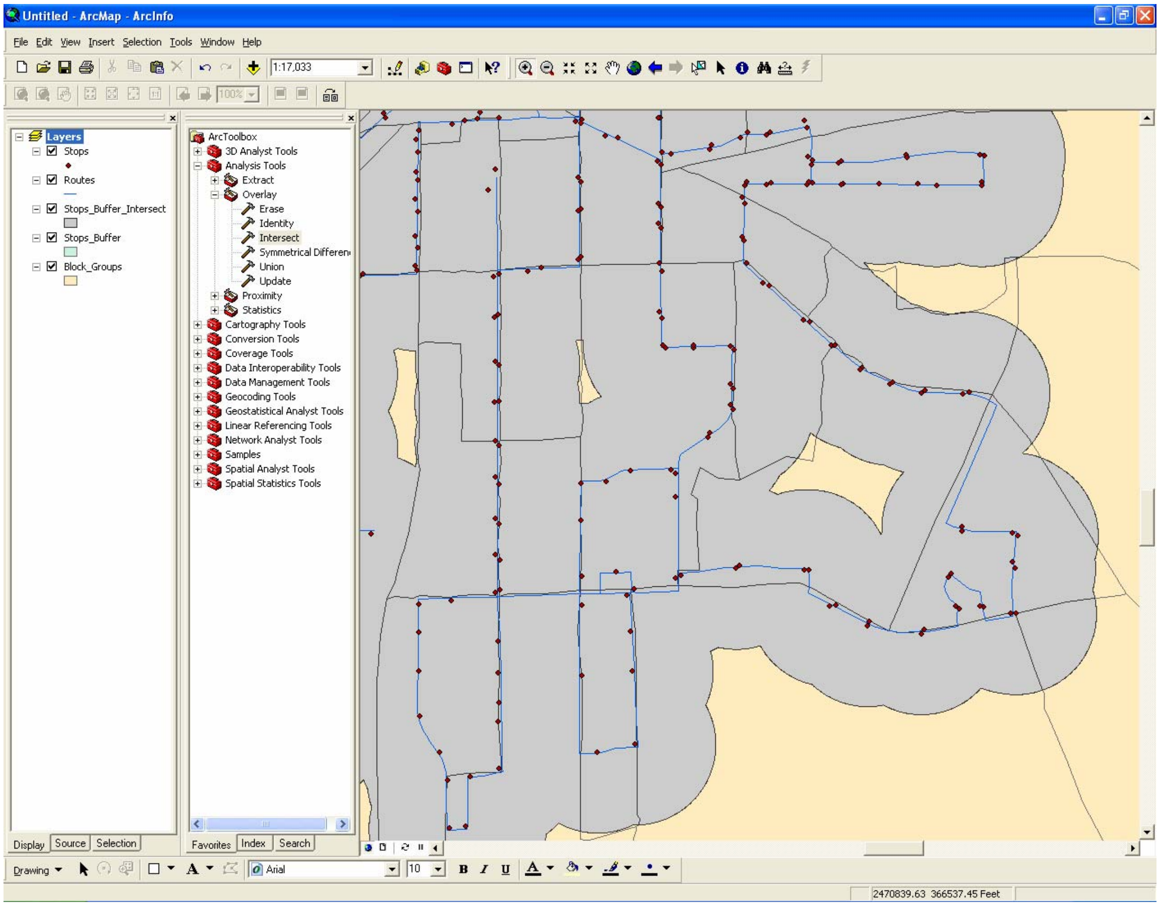
For 'Output Type', make sure that 'Input' is selected. Figure 22 shows what the dialog box should look like. Select 'OK'.

FIGURE 22: INTERSECT DIALOG BOX



Once the process concludes you will be able to see the results of the 'Intersect' if you zoom in. The gray areas below in Figure 23 show the areas of overlap or intersection.

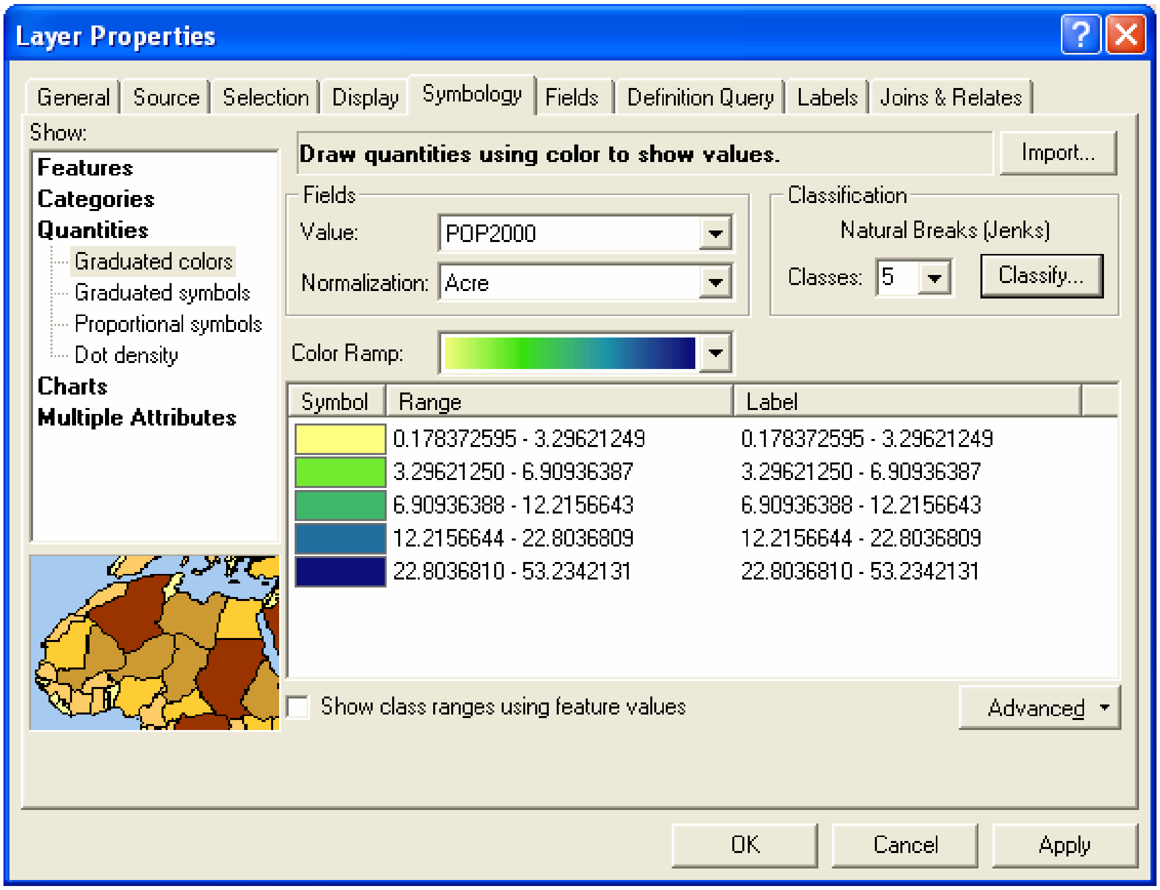
FIGURE 23: INTERSECT RESULTS ZOOMED IN



Step 7: System-wide Transit Service Analysis

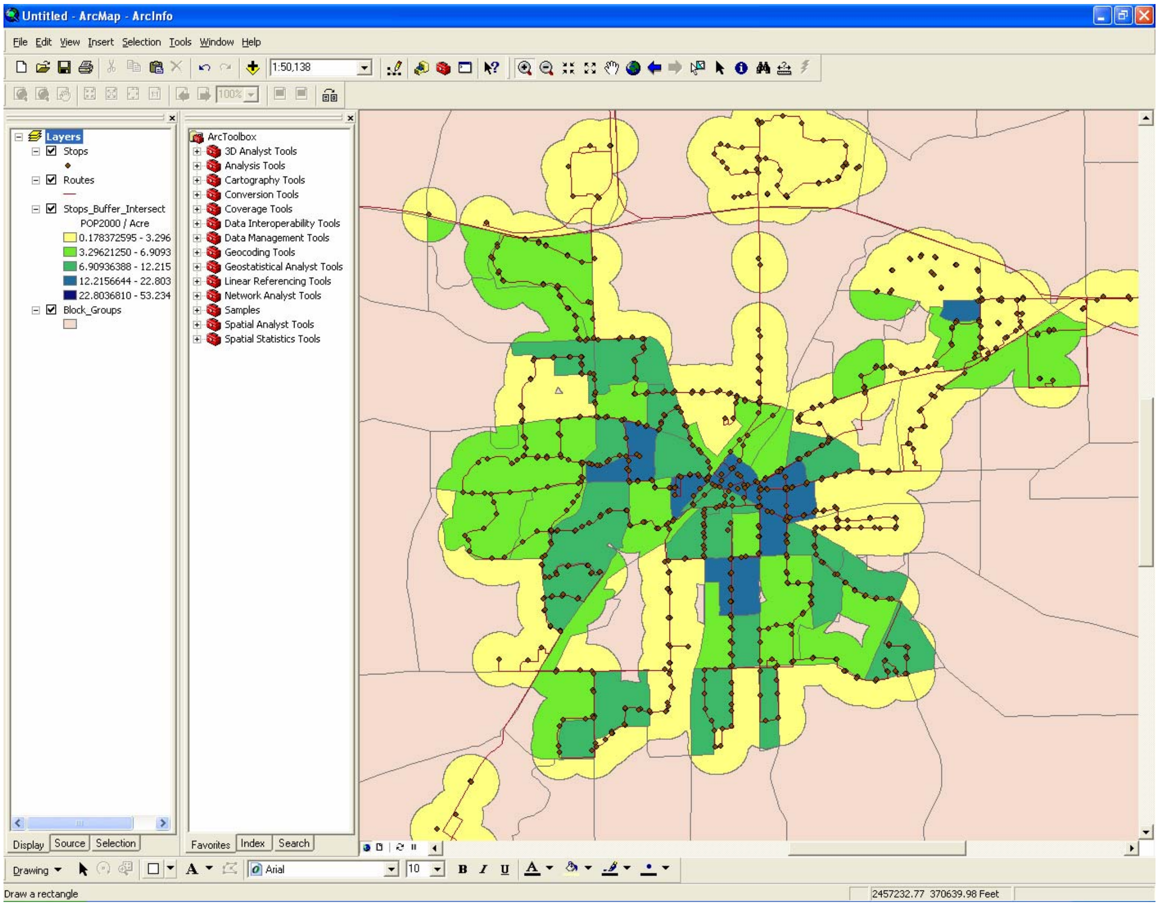
Once step 6 is complete we can analyze the transit service catchment area based on the socio-demographic data from the U. S. Census Bureau. To do this, begin by right-clicking on the 'Stops_Buffer_Intersect' layer and choosing 'Properties'. Then select the 'Symbology' tab and choose 'Quantities' and 'Graduated Colors'. Under 'Fields' in the 'Symbology' tab click the dropdown arrow for 'Value' and scroll down until you find the first variable you wish to use (we will use 2000 Population for our first example). Then for the 'Normalization' dropdown choose 'Acre' (or an area field for your polygons). By doing this we have created a measure of 2000 Population per Acre. Figure 24 shows the symbology created by this procedure.

FIGURE 24: SYMBOLOGY



There are a number of different ways to format categories. 'Color Ramp', 'Symbol', 'Range', and 'Label' can be changed in the 'Symbology' tab. You can also change the type of classification and the number of classes that your variable is split up into by clicking the 'Classify…' button in the upper right of the 'Symbology' tab. Specific formatting can be done by using with the different options until you find something that best suits your agency. Once you have found the best format click 'OK'. The symbology selected will be displayed fitting each polygon's attributes into one of the categories that were created. Figure 25 shows a zoomed-in view of the 2000 Population per Acre display.

FIGURE 25: ZOOMED-IN VIEW OF SYMBOLOGY RESULTS

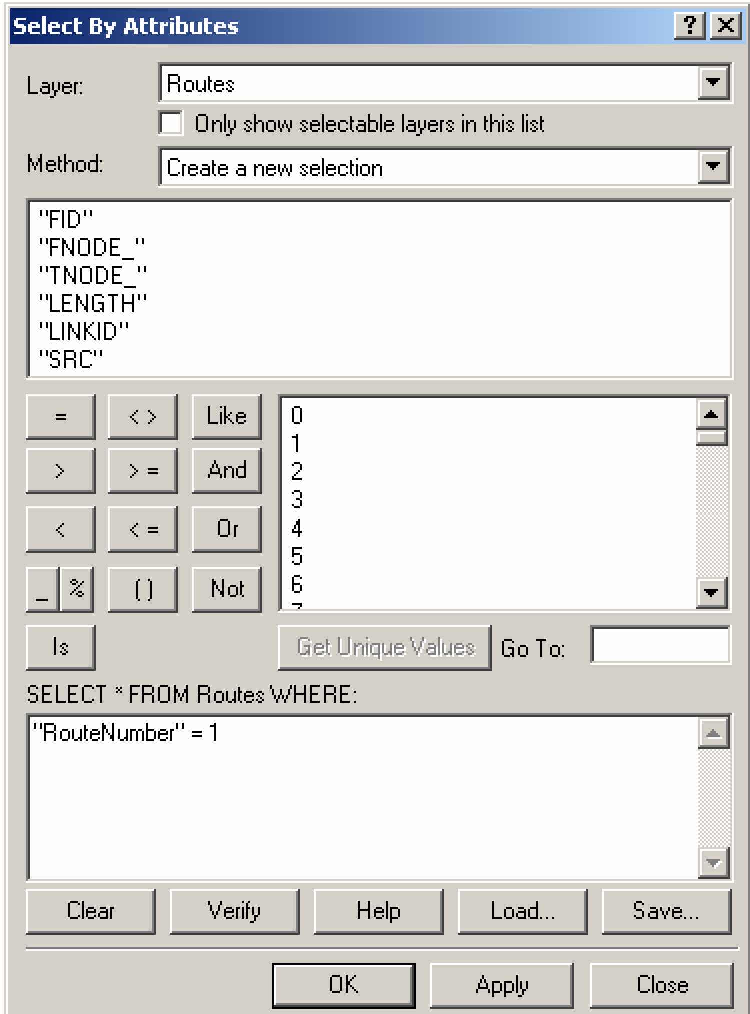


This step can be repeated for all the system wide performance measures that you wish to map out. I would recommend saving a new .mxd file for each variable.

Step 8: Selecting A Route

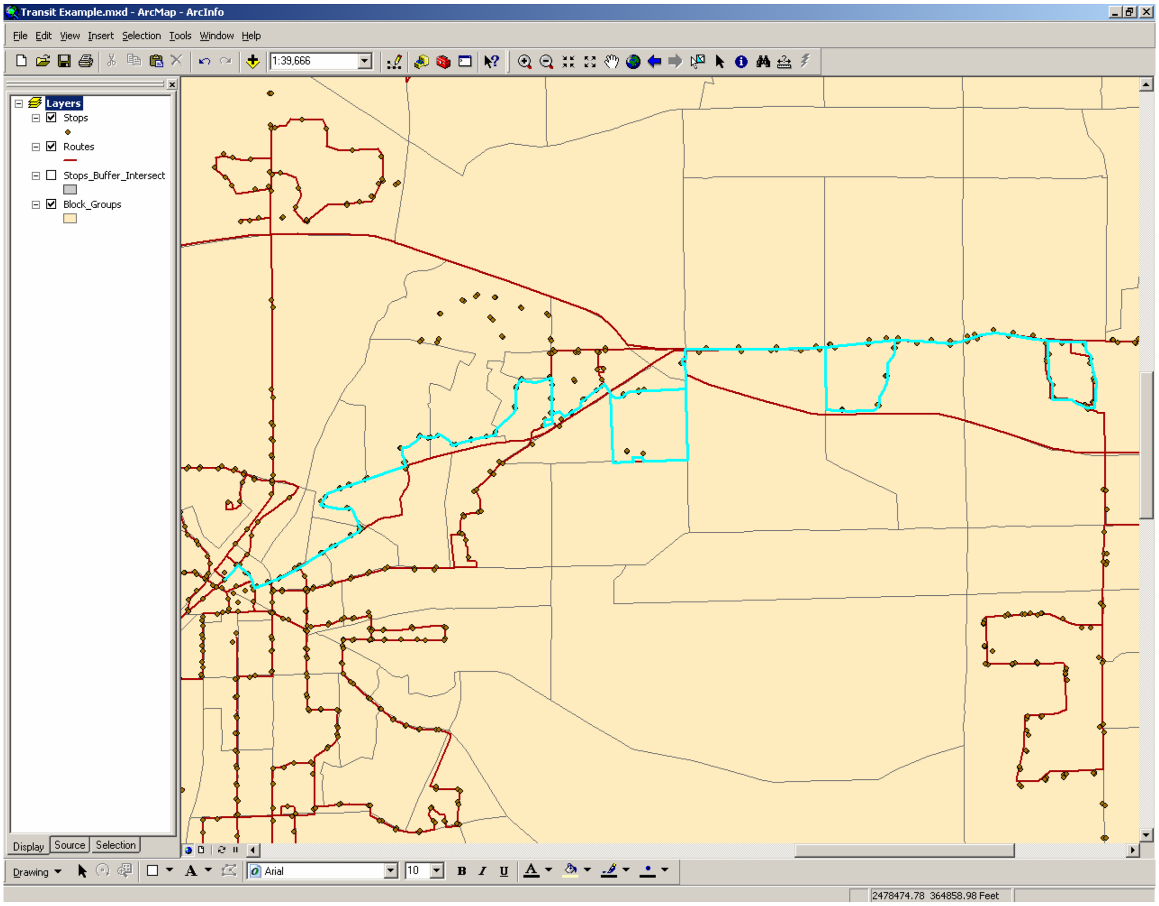
For the routes layer there should be a 'RouteNumber' field (if you do not have this field you will need to obtain data matching each link of the Routes layer to a route number). This field has the route number associated with each link of the Routes layer. Links for a specific segment are selected by going to the 'Selection' menu and choosing 'Select By Attributes'. For the 'Layer' dropdown choose 'Routes' layer. The 'Method' should be 'Create a new selection'. Where it says 'SELECT * FROM Routes WHERE' type in the following: "RouteNumber" = 1 (be sure that to use double quotations around the route number field, that you put one space before and after the equals sign, and that you put the route number of the route you wish to analyze after the equals sign). When everything looks like Figure 26 below click 'Apply' then 'OK'.

FIGURE 26: SELECT BY ATTRIBUTES DIALOG BOX



After hitting ‘Apply’ ArcMap will select each link of Route 1 (or the route chosen) and the route will be highlighted in light blue to show that it is selected. You can right click on the ‘Routes’ layer and choose ‘Selection’ and ‘Zoom To Selected Features’ to show the route zoomed in. Route 1 for Waukesha County is displayed in Figure 27.

FIGURE 27: ROUTE 1 SELECTED AND ZOOMED IN

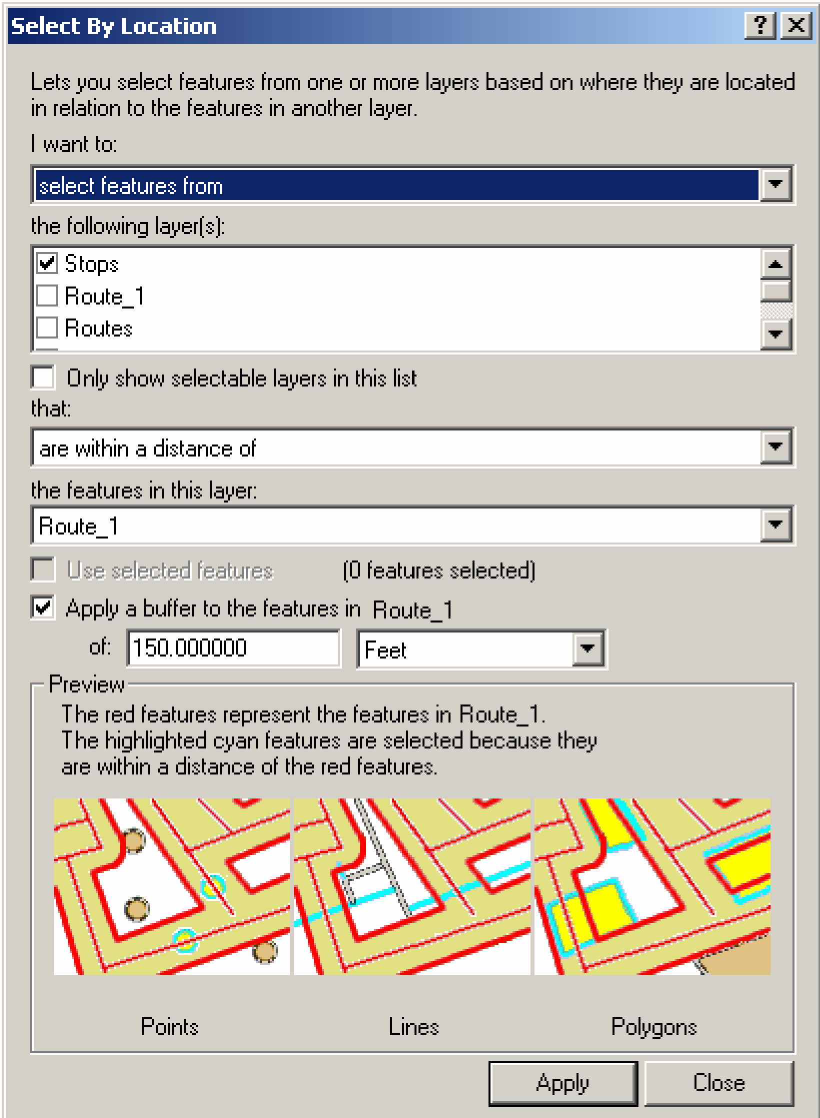


The selected route should be exported as its own layer. To do this, right click on the 'Routes' layer and choose 'Data' then 'Export Data'. You want to 'Export Selected Features' and 'Use the same coordinate system as this layer's data source'. Click the 'Browse' button  to choose the folder to save in, choose 'Save as type: Shapefile' and rename it 'Route_1' (or your route number). Click 'Save' and 'OK'. Click 'Yes' when asked if you want to add the new exported data to the map as a layer. When the 'Route_1' layer has been added, right click on the 'Routes' layer and choose 'Selection' then 'Clear Selected Features'. Also, uncheck the box next to the 'Routes' layer. You should see your route in the display (you may want to change the width and color of the line by double clicking the line symbol under 'Route_1').

Step 9: Creating A Route 1 Bus Stops Layer

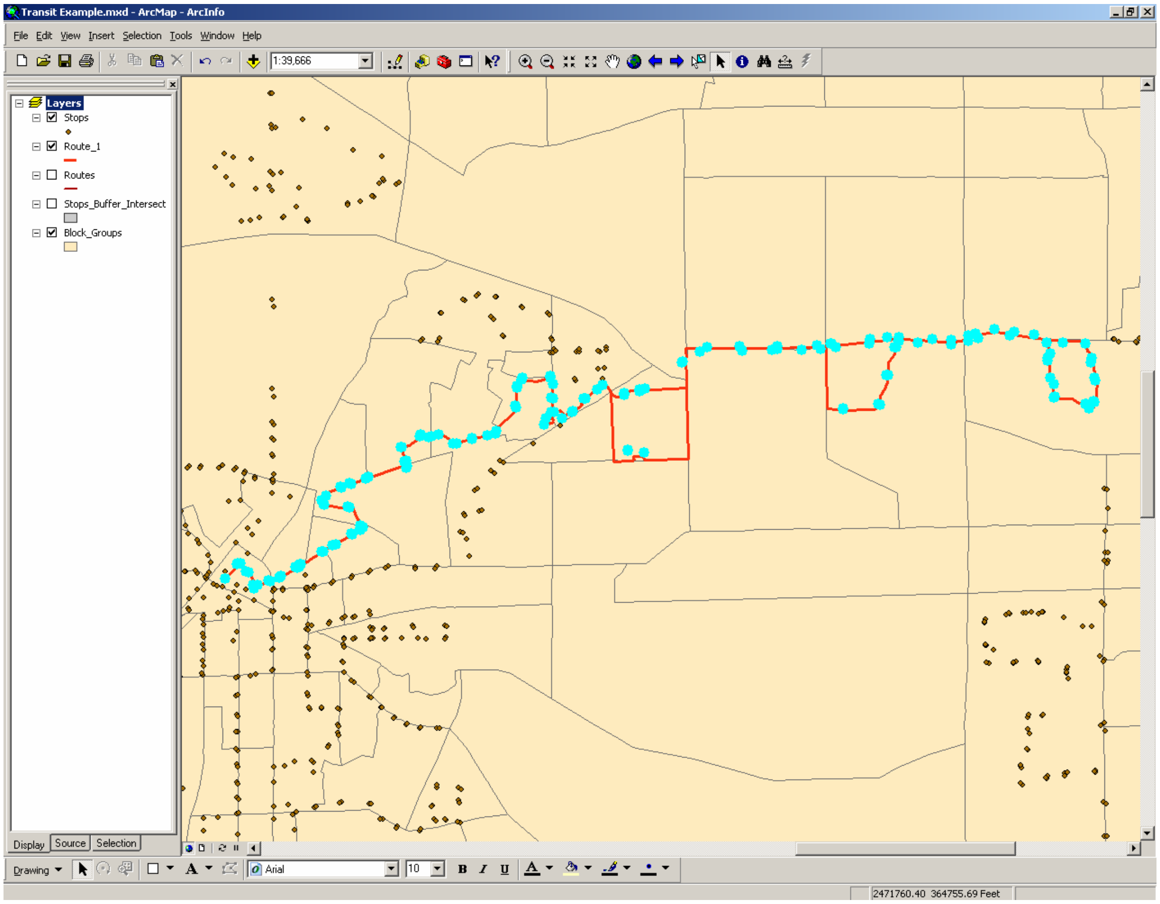
To select all the bus stops that are part of Route 1, go to the 'Selection' menu then choose 'Select By Location'. In this box, choose 'select features from', check the box next to 'Stops', choose 'are within a distance of', choose 'Route_1', leave the 'Apply a buffer to the features in Route_1' box checked, choose 'Feet', and type in '150' in the box next to 'Feet'. Click 'Apply'. Figure 28 shows the 'Select By Locations' dialog box.

FIGURE 28: SELECT BY LOCATION DIALOG BOX



This will select all the stops that are within 150 feet of the features in Route_1. You should visually inspect the selected features to make sure that they are indeed part of the Route 1's stops. To do this, click the 'Zoom In' button on the 'Tools' toolbar and click and drag a box around the area you want to inspect. If you want to add an additional stop or unselect a stop, go to the 'Selection' menu then select 'Set Selectable Layers…' and uncheck the box next to each layer except 'Stops'. To select an additional stop, go to the 'Selection' menu then select 'Interactive Selection Method' and 'Add to Current Selection'. To unselect a stop, go to the 'Selection' menu then select 'Interactive Selection Method' and 'Remove from Current Selection'. To add or unselect the stop, click the 'Select Features' button then click on the stop. Figure 29 shows the stops selected for Route 1.

FIGURE 29: ROUTE 1 BUS STOPS SELECTED

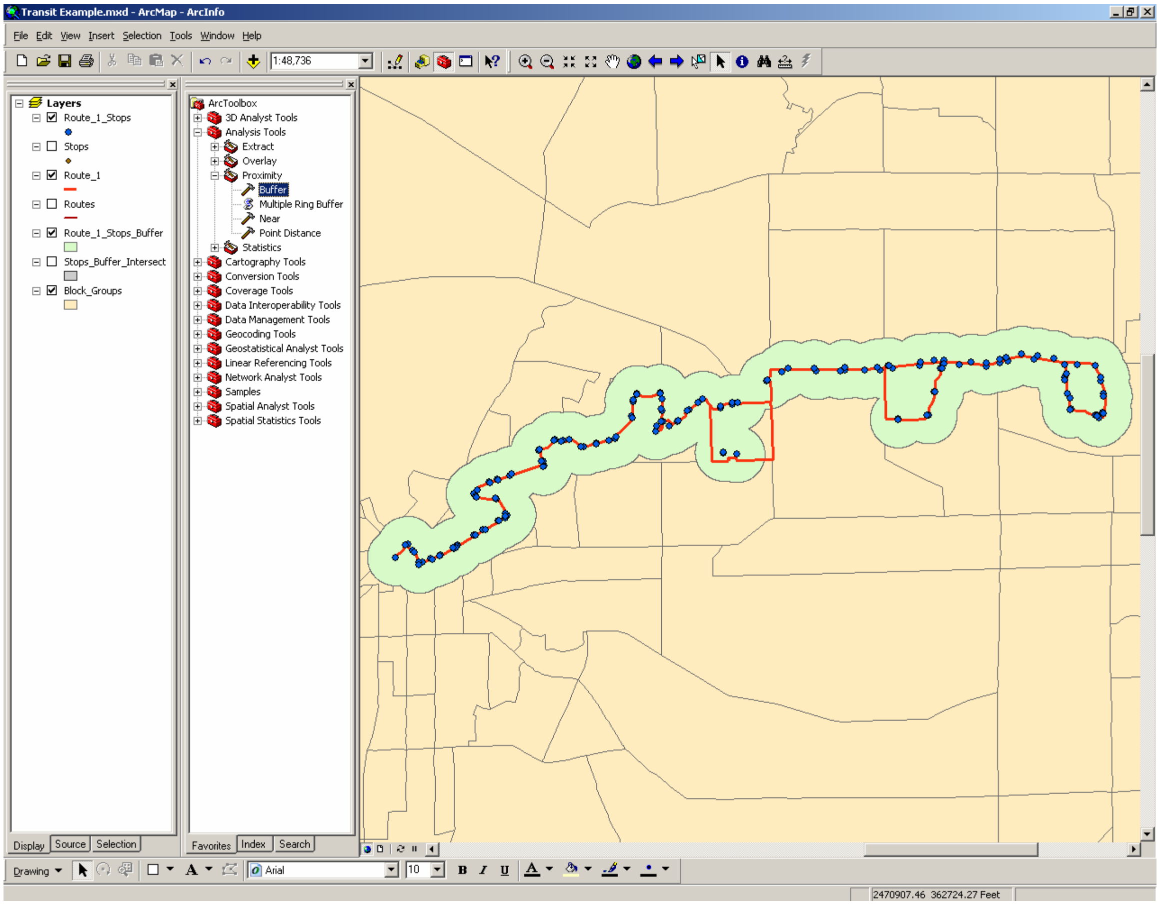


Once the stops have been selected you must export them as a new shapefile. Right click on the 'Stops' layer and choose 'Data' then 'Export Data'. You want to 'Export Selected Features' and 'Use the same coordinate system as this layer's data source'. Click the 'Browse' button to choose your folder to save in, choose 'Save as type: Shapefile' and rename it 'Route_1_Stops'. Click 'Save' and 'OK'. Click 'Yes' when asked if you want to add the new exported data to the map as a layer. Clear the selected features and uncheck the box next to the 'Stops' layer (you may also want to change the width and color of the symbol). You can now see the stops for Route 1.

Step 10: Buffering Route 1 Bus Stops

To buffer the 'Route_1_Stops' layer follow the same procedure as step 5. You will locate the transit service catchment area by buffering all locations within a quarter mile of each route 1 bus stop. To buffer, open ArcToolbox. Click on 'Analysis Tools', then 'Proximity' and choose 'Buffer'. This will launch the 'Buffer' dialog box. Choose the 'Route_1_Stops' layer as the 'Input Features' layer then click the 'Browse' button and navigating to the folder where you are saving your files and layers. Name the layer Route_1_Stops_Buffer. Under 'Distance' type in .25 for 'Linear unit' and choose 'Miles' from the drop-down menu. For 'Dissolve Type' choose 'ALL' then click 'OK'. You can see the transit service catchment area, shown in Figure 30, represented by the polygons of the 'Route_1_Stops_Buffer' layer.

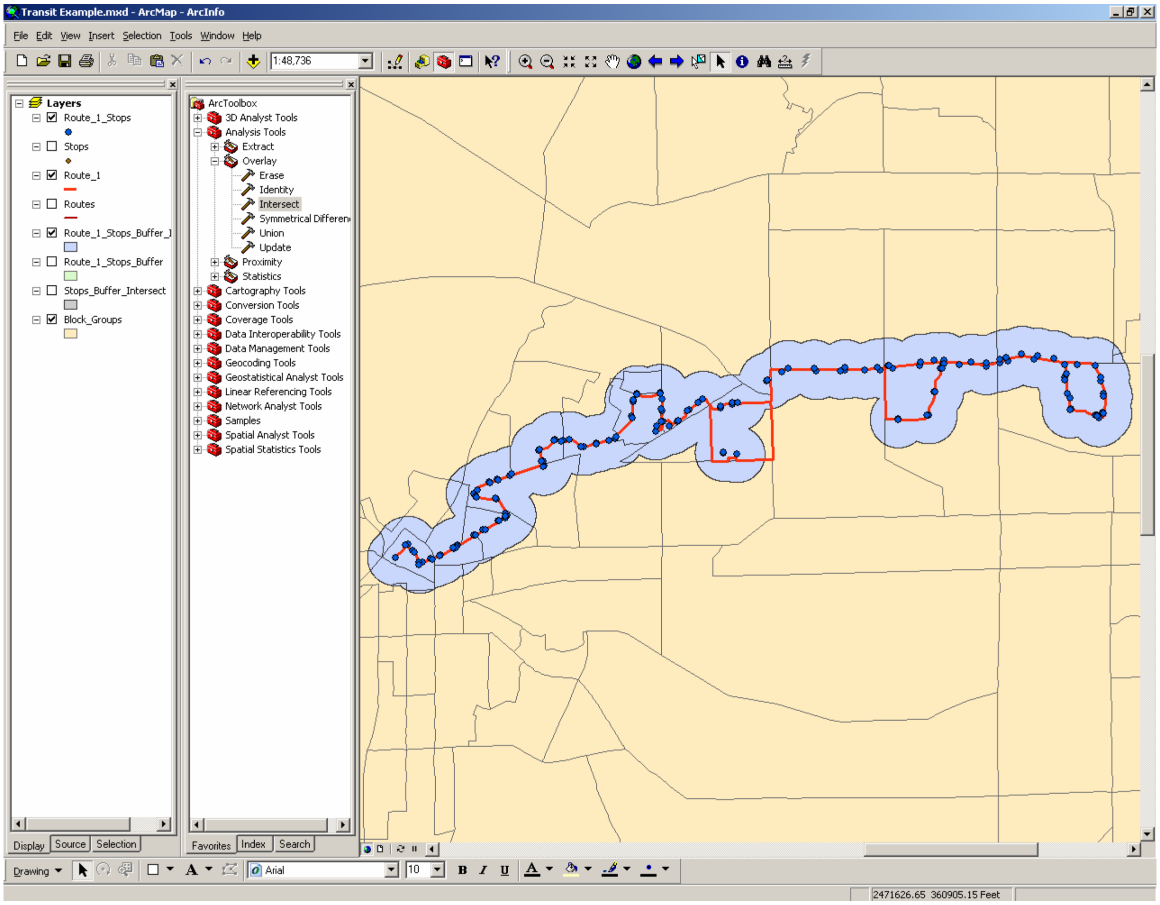
FIGURE 30: ROUTE 1 TRANSIT SERVICE CATCHMENT AREA



Step 11: Overlaying Route 1 Bus Stops Buffer with Census Block Group Data

Step 11 is a similar procedure to step 6. You now want to overlay the Route_1_Stops_Buffer layer with the Block_Groups layer. In ArcToolbox, select ‘Analysis Tools’, select ‘Overlay’, then ‘Intersect’. For ‘Input Features’ select both the Route_1_Stops_Buffer layer and the Block_Groups layer. Change the name of the ‘Output Feature Class’ to ‘Route_1_Stops_Buffer_Intersect’. Select the defaults for ‘Join Attributes’ and ‘Cluster Tolerance’. For ‘Output Type’, make sure that ‘Input’ is selected. Select ‘OK’. Once the process concludes you will be able to see the results of the ‘Intersect’. Figure 31 shows these results.

FIGURE 31: INTERSECT RESULTS ZOOMED IN



Step 12: Route Level Transit Service Analysis

Once step 11 is complete we can analyze the transit service catchment area based on the socio-demographic data from the U. S. Census Bureau. To do this, begin by right-clicking on the 'Route_1_Stops_Buffer_Intersect' layer and choosing 'Properties'. Then select the 'Symbology' tab and choose 'Quantities' and 'Graduated Colors'. Under 'Fields' in the 'Symbology' tab click the dropdown arrow for 'Value' and scroll down until you find the first variable you wish to use (we will use Households with No Vehicles for our first example). Then for the 'Normalization' dropdown choose the field you want the variable normalized by (we will use Total Households). By doing this we have created a measure of Households with No Vehicles per Total Households.

As previously discussed in step 7, there are a number of different ways to format your categories. Once you settle on a format your Households with No Vehicles per Total Households will display with the symbology you have chosen. This step can be repeated for all the route level performance measures that you wish to map out. It is recommended that you save a new .mxd file for each variable.

Step 13: Making a Map Document with the Layout View

The next step is to make a map document of each system-wide and route level performance measure you have used. Go to the 'View' menu and select 'Layout View' instead of 'Data View'. You can now add the proper items to your map document (Title, Legend, North Arrow, Scale Bar, etc.). To do this, first and select 'Layout View'. From here there are an unlimited number of ways to arrange the items of your map document. You can resize your map image by clicking one of the blue squares along the outside of the image and you can move the image by clicking and dragging it. Make sure you keep what you want displayed in the map document inside the outlined box.

To add items to your map document use the 'Insert' menu. To add a title, go to the 'Insert' menu and select 'Title'. Type in what you want the title to be and press Enter or click anywhere outside the text box. You can edit the title by double-clicking on it. You can also click 'Change Symbol…' to edit the font type, size, etc. Once your title is acceptable, go to 'Insert' and choose 'Legend…' to bring up the 'Legend Wizard'. The first box allows you to choose which layers you want included in your legend. Use the multiple arrow buttons to move all layers back and forth and the single arrow buttons to move a single layer back and forth. After clicking 'Next', you are allowed to change the title of the legend. After clicking 'Next' again you are given options on the 'Border', 'Background', and 'Drop Shadow' of your legend. Click 'Next' to be able to change the symbols that will appear for each layer in the legend. Clicking 'Next' one final time you are given a choice of spacing options. Once you are satisfied with your selections, click 'Finish'. Your legend will appear. The next item is the north arrow, which can be added using the 'Insert' menu and clicking on 'North Arrow…'. Choose your north arrow and click 'OK'. The last item that every map should have is the scale. For this you can use a scale bar, scale text, or both. For the scale bar, go to 'Insert' and choose 'Scale Bar…'. Choose your scale bar. For the scale text, go to 'Insert' and choose 'Scale Text…'. Choose your scale text. Once you have added all necessary map items move them around and resize them to your liking.

Step 14: Exporting Map as A PDF File

The final step to creating a map document is to export it as a PDF. A PDF does not retain the functionality of an ArcMap .mx file. To export as a PDF, go to 'File' then 'Export Map'. When the dialog box pops up locate the folder you want to save in and change the 'Save as type:' dropdown to 'PDF (*.pdf)'. You can name the file the same name as your .mxd file for that measure but make sure you do not change the .pdf at the end of the name. Click 'Save'. Do this for each map. You can then view them by opening them in Acrobat Reader.

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APPENDIX 1: SURVEY FORM USED IN PROJECT

PART I. MEASURING TRANSIT PERFORMANCE

1. Do you use transit performance measures in your service and operation planning and evaluations? ☐ YES ☐ NO (If no, please skip to question 8)

   ➢ If yes, why do you use transit performance measures? (Please check all that apply)

   ☐ (A) They are required for the National Transit Database
   ☐ (B) They are useful to maintain and improve service
   ☐ (C) They are needed to measure whether agency goals are being met
   ☐ (D) They are needed to measure whether community goals are being met
   ☐ (E) They are needed to report to decision-making bodies
   ☐ (F) They are needed to report to the public
   ☐ (G) Others (please specify)

____

2. How important are the following transit performance indicators? (Please circle the number on a 5 point scale from 1 = "Not Important" to 5 = "Very Important")

	Not Important			Very Important
A. Avoidable accidents per vehicle-hour/vehicle-mile……	1	2	3	4	5
B. Complaints per driver/trip…………………………………	1	2	3	4	5
C. Expense per vehicle-hour/vehicle-mile……………	1	2	3	4	5
D. Fare box recovery rate……………………………..	1	2	3	4	5
E. Load Factor……………………………………….…	1	2	3	4	5
F. Passengers per vehicle-hour/vehicle-mile……..	1	2	3	4	5
G. Revenue per vehicle-hour/vehicle-mile…………	1	2	3	4	5
H. Others (please specify) ____________________.	1	2	3	4	5

3. What do you feel are the 5 most important performance measures that your system uses? (Please list 5 measures-they do not need to be in any particular order)

   (1) ____
   (2) ____
   (3) ____
   (4) ____
   (5) ____

4. What are your sources of data? (Please check all that apply)

   ☐ (A) Accident Reports
   ☐ (B) Automatic Passenger Counter (APC) Systems
   ☐ (C) Automatic Vehicle Location (AVL) Systems

☐ (D) Complaints
☐ (E) Data collected in-house or from other field surveys
☐ (F) Fare box data or other accounting reports
☐ (G) Others (please specify)

____

5. Did you collect it differently in the past? ☐ YES ☐ NO

➢ If so, what method(s) did you use? (Please list all past methods)

(1) ____
(2) ____
(3) ____
(4) ____

6. Have you incurred any problems trying to collect data? ☐ YES ☐ NO

➢ If so, what problems have occurred? (Please check all that apply)

☐ (A) Data inconsistencies or measuring error
☐ (B) High costs
☐ (C) Inadequate equipment
☐ (D) Limited data/measures available
☐ (E) Time consuming
☐ (F) Unwillingness of participants to cooperate
☐ (G) Others (please specify)

____

7. Which of the following data sources are used for analysis? (Please check all that apply)

☐ (A) Local planning agencies
☐ (B) Local public works department
☐ (C) National Transit Database (NTD)
☐ (D) State Department of Transportation (DOT)
☐ (E) U.S. Census Bureau
☐ (F) Others (please specify)

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PART II. USE OF GEOGRAPHIC INFORMATION SYSTEMS (GIS)

8. Does your transit agency have a GIS software program that it can use?

☐ YES ☐ NO

➢ If no, why not? (Please check all that apply)

☐ (A) Lack of personnel to implement/maintain software program
☐ (B) No budget for software programs
☐ (C) Not necessary in a small transit agency
☐ (D) Software not available
☐ (E) Software not user friendly

☐ (F) Too costly
☐ (G) Others (please specify)

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9. Do you use GIS and/or GPS to collect data? ☐ YES ☐ NO

➢ If no, why not? (Please check all that apply)

☐ (A) Lack of personnel to implement/maintain software program
☐ (B) No budget for software programs
☐ (C) Not necessary in a small transit agency
☐ (D) Software is not user friendly
☐ (E) Too costly
☐ (F) Others (please specify)

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10. Do you use GIS to analyze or report performance data? ☐ YES ☐ NO

➢ If yes, please go to question 11

➢ If no, why don't you use GIS? (Please check all that apply and skip to 12)

☐ (A) Lack of personnel to implement/maintain software program
☐ (B) Software is not user friendly
☐ (C) Others (please specify)

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11. How important is GIS in measuring performance at each of the following levels?

	Not Important	-------	-------	-------	Very Important
A. System Level………………………………..	1	2	3	4	5
B. Route/Route Segment Level………………...	1	2	3	4	5

PART III. USE OF OTHER TECHNOLOGIES

12. Do you have an Automatic Vehicle Location (AVL) system?

☐ YES ☐ NO

➢ If yes, do you feel that this technology has improved on time performance?

☐ YES ☐ NO

13. Do you think that AVL can be used to measure transit performance?

☐ YES ☐ NO (If no, please go to 14)

➢ If yes, do you currently use AVL for the purpose of transit performance measurement?

☐ YES ☐ NO (If no, please go to 14)

- If yes, what performance indicators does AVL produce? (Please check all that apply)

☐ (A) Average dwell time at stops
☐ (B) On time performance
☐ (C) Percent of route deviation
☐ (D) Response time to accidents or breakdowns
☐ (E) Others (please specify)

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14. Do you have Automatic Passenger Counters (APC)?

☐ YES ☐ NO (If no, please go to 15)

- If yes, do you feel that this technology has produced useful information?

☐ YES ☐ NO

15. Do you think that APC can be used to measure transit performance?

☐ YES ☐ NO (If no, please go to 16)

- If yes, do you currently use APC for the purpose of transit performance measurement?

☐ YES ☐ NO (If no, please go to 16)

- If yes, what performance indicators does APC produce? (Please check all that apply)

☐ (A) Fare box recovery rate
☐ (B) Load Factor
☐ (C) Passengers per stop
☐ (D) Passengers per vehicle-hour/vehicle-mile
☐ (E) Others (please specify)

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16. Do you use other technologies? ☐ YES ☐ NO

- If so, what are they? (Please list all others)

(1) ______________________________
(2) ______________________________
(3) ______________________________
(4) ______________________________
(5) ______________________________