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A PILOT APPLICATION STUDY OF CORRIDOR PERFORMANCE INDICATORS

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ABSTRACT

The need for effective multimodal performance indicators (or measures) is becoming increasingly important for adequate planning in all sizes of transportation environments, including small and medium-size communities. These measures are essential for several reasons. First, an initial determination of performance by measuring existing conditions indicates the degree of needed improvements. Second, after improvements are implemented, measurement of their performance is often required. Third, such measures are beneficial for measuring roadway improvements examined within the context of the Transportation Equity Act for the 21st Century (TEA21). Finally, multimodal measures can be used to monitor the performance of the transportation system over time by examining changes in performance from an established base year.

The purpose of this paper is to report on the testing of selected multimodal corridor performance measures for a small and medium-size area, including an evaluation of the amount and cost of required data. These measures are either based on corridor volume to indicate quantity of travel, or on time to indicate quality. Measures of corridor quantity include person throughput, vehicle miles of travel, and average vehicle occupancy. Measures of quality include average travel time, average travel speed, density, and percent time heavily congested.

The measures are developed and tested within a 5-mile segment along I-95 in the City of Hollywood (population of 127,000 in 1997), located in Broward County in southeast Florida. While this city is surrounded by a much larger developed area, the test area serves the purpose of illustrating the applicability of the selected performance measures as well as data collection and cost elements for a small and medium-size area. The corridor also contains a commuter train service (Tri-Rail) that is operated by the Tri-County Commuter Rail Authority. Several types of

highway and transit data were collected along the corridor.

One key concern regarding the application of these measures in small and medium-size areas is the cost and method of data collection. This is because some measures may require new data that may be difficult or expensive to obtain, resulting in an extra financial burden on the smaller urban area where the competition for scarce tax or other revenue resources is high. This concern is addressed and several inferences regarding data collection and system utilization are made from this study. The results presented in this paper can be extended to apply to several classes of roadways/transportation corridors, and should benefit those responsible for the implementation of transportation corridor improvements in small and medium-size areas.

A PILOT APPLICATION STUDY OF CORRIDOR PERFORMANCE INDICATORS

INTRODUCTION

The need for effective multimodal transportation performance indicators (or measures) is becoming increasingly important for adequate planning in all sizes of transportation environments, including small and medium-size communities. These measures are essential for several reasons. First, an initial determination of performance by measuring existing conditions indicates the degree of needed improvements. Second, after improvements are implemented, measurement of their performance is often required. Third, such measures are beneficial for measuring roadway improvements examined within the context of the Transportation Equity Act for the 21st Century (TEA21). Finally, multimodal measures can be used to monitor the performance of the transportation system over time by examining changes in performance from an established base year.

The development and implementation of a single measure to describe multimodal performance is not recommended. This is because one measure cannot adequately depict the performance of all modes, may not be sufficiently sensitive to indicate a change in performance, and is not likely to achieve all the goals and objectives defined for measuring performance. As such, several measures should be used that would satisfy the needs of management while meeting other specific technical needs.

A wide variety of existing performance measures have been reported in the literature. The most common measures are based on traffic volume (vehicle flow) and person movement. Examples of volume-based measures include vehicle miles or vehicle hours of travel [1]. Travel time, speed, and delay measures include total travel time, running time, and speed; in addition to delay rate and delay ratio [1,2]. Person movement measures include person volume and person miles or person hours of travel [3,4,5]. Finally, examples of transit measures include frequency of service, riders per vehicle mile, and load factor [3,4].

The purpose of this paper is to report on the testing of selected multimodal corridor performance measures for a small and medium-size area, including an evaluation of the amount and cost of data necessary to apply these measures. The City of Hollywood (population of 127,000 in 1997), located in Broward County in southeast Florida was selected for the analysis. The results from the study can be extended to apply to several classes of roadways/transportation corridors in small and medium-size areas, and should benefit those responsible for the implementation of transportation corridor improvements. This analysis is part of an on-going pilot application study conducted by the Florida Department of Transportation (FDOT) to examine the applicability of performance measures along a 46-mile corridor in southeast Florida that included three counties (Miami-Dade, Broward, and part of Palm Beach). FDOT is in the process of developing appropriate multimodal measures of performance, and is planning to prepare a *Mobility Performance Measures Handbook* for statewide use in late 1999.

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The paper is organized into six sections following this introduction. The *first section* reviews the alternative corridor performance measures used in the study. These measures are selected based on an extensive review of measures examined or used by other agencies in numerous states [4], and on an analytical procedure for the recommendation of multimodal measures [5]. The *second section* describes the characteristics of the study area which includes both highway and transit. The *third section* presents the alternative data collection methods used in this study for both modes. This includes data about the corridor collected in the field or obtained from historic databases. The *fourth section* presents key results of the study, reported in terms of several spatial and temporal parameters that characterize each measure. The *fifth section* provides some valuable insights concerning the results and their applicability to small and medium-size areas in terms of data collection needs and methods. The *final section* provides a summary of the study.

CORRIDOR PERFORMANCE INDICATORS

There are numerous performance measures that are either used or proposed for the evaluation of transportation systems in small and medium-size areas. Some of these measures are simple and widely understood while others are more complicated and less known. These measures are likely to evolve over the next few years, reflecting the experience and knowledge gathered from different studies, and the changing needs of management. The wide variety of existing measures has necessitated the need for the development of an analytic process to ensure that performance measures are not selected arbitrarily; instead, they are based on a pre-determined and systematic methodology. This methodology includes a screening process in which a representative group of measures is selected from the list of existing measures based on an established set of minimum criteria. It also includes a prioritizing process in which a number of primary and secondary attributes that characterize each measure are defined and rated. Finally, the process includes the development and application of a scoring function that assigns numeric values to the representative measures, and the selection of measures with the highest scores. A detailed description of this analytic methodology and the scoring function are presented elsewhere [5,6].

The resulting performance measures from this process are being tested in this paper for their applicability in small and medium-size areas. They are either based on corridor volume to indicate quantity of highway and transit travel, or on time to indicate quality of travel. They can be used together to identify and assess the overall performance of corridors, identify problems, evaluate and compare alternative improvement strategies, and monitor these corridors over time. Each of these groups include measures classified as either primary or secondary. Primary measures are most important for measuring performance; secondary measures augment and verify primary measures.

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- **Measures of Corridor Quantity (volume)**

  - *Person throughput (or person volume)* is the primary measure of effectiveness. It represents the total number of people moved within or through a corridor during a time period. The measure is expressed in total persons for highway analysis, and in total passengers for transit.

  - *Vehicle miles of travel* is the product of the total number of vehicles in the corridor at a particular time and the total number of miles that these vehicles travel. It is expressed in vehicle miles for highways, and in bus (or train) miles for transit.

  - *Average vehicle occupancy* is the average number of occupants per vehicle. It is expressed in persons per vehicle for highways, and in passengers per bus (or train) for transit. This measure is essential for the development of a person throughput measure.

- **Measures of Corridor Quality (time)**

  - *Average travel time* is the primary measure of efficiency. The measure represents the average time required to traverse the corridor, and is expressed in minutes of travel for highway and transit.

  - *Average travel speed* is expressed in miles per hour for highway and transit. It represents the average speed of all vehicles in the corridor. Data for this measure can be obtained in conjunction with traffic counts collected in the field, or can be derived from roadway distance and travel time data.

  - *Density* is expressed in vehicles per lane mile for highways, and in passengers per seat for transit. This measure provides little information about the movement of vehicles in highly congested corridors.

  - *Percent time heavily congested* is the percentage of time in which highway and transit demand exceed capacity as indicated by the Level of Service (LOS) standards established for the particular type of facility.

These selected measures may be sensitive to extraordinary conditions. As such, these measures should normally be used under typical conditions, because they may provide misleading results or conclusions in situations where extraordinary conditions exist.

Extraordinary conditions include several transportation and non-transportation events. For example, a change in posted speed limits can influence the performance of a highway. The elimination of parking along an arterial, or the widening of an existing roadway both obviously influence roadway performance. Transit systems are vulnerable to changes in fares, route structure, and other operational decisions.
Non-transportation events include a change in the price of fuel and the general health of the economy, both of which can influence individual travel patterns. In addition, local land use

decisions including taxing regulations can influence land development patterns, thereby, affecting the performance of the transportation system. These and other similar events are not considered or examined in this paper.

CHARACTERISTICS OF THE STUDY AREA

The City of Hollywood (population of 127,000 in 1997) is located in Broward County in southeast Florida between Fort Lauderdale and Miami. Interstate 95 (I-95) is the primary north-south limited access facility that crosses the center of the city, providing a connection between several small and medium-size urban areas in the region. It consists of eight general-purpose lanes and two HOV lanes that extend throughout the corridor in both directions. Other major complementary roadways that serve the same origin/destination patterns in the vicinity of I-95 include Florida's Turnpike, US 1, and US 441.

The 5-mile segment along I-95 in Hollywood is selected for applying and testing the multimodal corridor performance measures. This corridor is heavily traveled by commuters who use I-95 for their daily trips to/from work, and by both in-state and out-of-state tourists who travel within the region. As such, the corridor is frequently congested; particularly, during the peak hours. For example, an estimated average daily traffic of 295,000 vehicles was observed on I-95 near Hollywood in 1997. In addition, due to travel convenience resulting from the large number of access points along the facility, the corridor is a primary truck route (more than 17,000 daily truck trips were observed in 1997) for increasing freight movements.

The corridor also contains a commuter train service (Tri-Rail) that was established in 1989. The train system is operated by the Tri-County Commuter Rail Authority, an agency of the state of Florida. Tri-Rail runs parallel to I-95, and provides service to the public on weekdays as well as weekends. It has an extensive network of feeder service, including free Tri-Rail shuttle bus service from most stations and free connections to county bus service to downtown Miami.

The system operates between the hours of 4:00 A.M. and 11:00 P.M. on weekdays, between 5:30 A.M. and midnight on Saturdays, and between 8:00 A.M. and 8:30 P.M. on Sundays. On a typical weekday, six northbound trains are operational during the morning period, while eight similar Tri-Rail trains are operational during the afternoon. The corresponding number of southbound weekday trains is seven for both periods. On the weekend, three northbound trains are operational during the morning period, while either four or five trains are operational during the afternoon period. The corresponding number of southbound weekend trains is between three and four for both periods. The capacity of each train is 600 passengers.

The Tri-Rail system is comprised of 6 zones, and weekday ticket prices are determined by the number of zones through which a passenger travels. The one-way fare for trips within the same zone is $2.00, while the corresponding fare for trips made through all six zones is $5.50. Several types of discounts are available including one-way discounts, round-trip discounts, monthly discounts, and weekend/holiday discounts.

DATA COLLECTION

Several types of highway and transit data were collected along the corridor. Field data collection took place during the fall school year so that the collected data would represent average daily traffic patterns. Further, in order to reduce the potential for obtaining biased indicators of roadway performance, no highway data was collected during holidays, periods of inclement weather, or major sporting events.

Highway data included traffic volume counts, speed, travel time, and vehicle occupancy. Standard roadway service volume at congestion was also calculated. Hourly traffic counts and spot speed data was obtained from the Transportation Statistics Office (TSO) of FDOT at one Traffic Count Telemetry System (TTMS) site along the corridor. The data was obtained in both directions for three consecutive weekdays in September 1997 along the HOV lanes and several general-purpose lanes. Travel time information was obtained from a previous study for FDOT [7] in which 48 travel time runs were conducted along the corridor using the floating car method. This information was collected during the morning and evening peak hours (7:00 to 9:00 A.M. and 4:00 to 6:00 P.M.). Vehicle occupancy data was collected for one day during peak hours in both directions along the HOV lane and along one general-purpose lane using the *carousel method* of observation. This method is sometimes used for collecting vehicle occupancy data on multilane routes with high traffic volumes. It involves an observer and a driver, both traveling in a car that is operated to move slightly slower than the general speed of traffic (vehicle occupancy is therefore determined for vehicles that pass the observer). The carousel method allows a better view of the front and rear seat passengers, especially in vans and automobiles with tinted windows. Standard roadway service volume at congestion (i.e., service flow rate at LOS D as defined for this type of facility) was calculated using procedures from the 1994 Highway Capacity Manual (HCM), and used to establish congestion standards for the corridor.

Transit data was obtained from the Tri-County Commuter Rail Authority that operates the Tri-Rail commuter train service in the southeast region. This data included monthly ridership by station, travel direction, time of day, day of week, and train for a period of one year (1996). It also included information about scheduled travel time for trains between stations during the same time period.

MAJOR RESULTS

This section presents the results of the analysis of highway and transit measures for the pilot corridor. The indicators include person throughput, average travel time, vehicle miles of travel, average vehicle occupancy, average travel speed, density, and percent time heavily congested. They are reported in relation to a set of unique spatial and temporal parameters that are consistent with guidelines for reporting multimodal performance, and are tailored to the amount of detailed data that is available for each mode.

Highway spatial parameters include lane classification (HOV and general purpose lanes) and direction (northbound and southbound), while temporal parameters include time of day (morning peak and evening peak). For the purpose of this study, the morning peak represents the hours between 7:00 A.M. and 9:00 A.M., and the evening peak represents the hours between 4:00 P.M. and 6:00 P.M. Transit spatial parameters include direction (northbound and southbound), while temporal parameters include time of day (A.M. and P.M. periods), and day of week (weekdays and weekends).

The results of the highway performance indicators are presented in **Table 1**. The person throughput measure is based on average vehicle occupancy and traffic counts, and reported as the number of persons carried through the corridor during a time period. As such, the corridor carries approximately 27,600 persons northbound during the peak hours every day (20 percent are in the HOV lane). Similarly, approximately 22,800 persons travel southbound along the corridor during the same period every day (18 percent are in the HOV lane). The vehicle miles of travel (VMT) measure is based on traffic counts and traveled distances, and reported as an average daily estimate. On average, total daily VMT during peak hours is approximately 0.13 million northbound and 0.11 million southbound. Average vehicle occupancy is based on a sample of traffic vehicles, and reported as the average number of occupants in a vehicle during a time period. The results indicate that average vehicle occupancy in the HOV lane is 1.42 northbound and 1.39 southbound. These numbers are relatively low, suggesting the need for increased lane enforcement. The corresponding vehicle occupancy for the general purpose lanes is 1.11 in both directions. Average travel time for the corridor is between 4 and 5 minutes. Total time savings in the HOV northbound direction during the evening peak hours are 21 seconds (or 7 percent), while the corresponding savings in the HOV southbound direction during the morning peak hours are 18 seconds (or 6 percent). As such, annual time savings to commuters traveling on I-95 in the vicinity of the city of Hollywood are approximately three hours per person assuming regular use. Average travel speed in the HOV lane is higher than the corresponding travel speed in the general purpose lanes, suggesting better highway travel conditions. Also, the difference between spot and computed speed is relatively small (less than 10 percent), indicating the potential for using one speed measure as a surrogate for the other. Average roadway density in the HOV lanes is approximately 12 vehicles per lane mile compared to 18 vehicles per lane mile in the general purpose lanes. Finally, the results indicate that the corridor is heavily congested (i.e., LOS D for this type of facility) between 15 and 16 percent of the day northbound and between 16 and 17 percent southbound.

Table 1

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Highway Performance Indicators
Average Daily Results

Type	Description		Northbound				Southbound			
			AM Peak		PM Peak		AM Peak		PM Peak	
			HOV	Other	HOV	Other	HOV	Other	HOV	Other
Measures of Quantity	**Person Throughput** (in thousands)		2.60	9.40	3.00	12.60	1.20	6.60	2.90	12.10
	Vehicle Miles of Travel (in thousands)		9.80	49.00	12.30	59.60	5.00	34.60	11.40	57.40
	Avg. Vehicle Occupancy (persons per vehicle)		1.47	1.06	1.37	1.17	1.35	1.05	1.42	1.17
Measures of Quality	**Avg. Travel Time** (minutes)		4.50	5.00	4.80	5.15	4.50	4.80	4.95	4.92
	Avg. Travel Speed	**Spot speed** (miles per hour)	75.80	64.80	74.00	64.40	77.10	65.70	74.10	63.70
		Computed speed (miles per hour)	74.10	65.80	69.20	64.50	74.10	68.80	67.90	67.50
		Difference (percent)	2.3%	1.5%	6.9%	0.2%	4.0%	4.7%	9.1%	6.0%
	Density (vehicles per lane mile)		11.70	17.10	15.00	20.90	13.90	20.30	5.90	11.90
	Time Heavily Congested (percent)		15%	16%	15%	16%	16%	17%	16%	17%

The results of the Tri-Rail transit performance indicators are presented in **Table 2**. The person throughput measure for the corridor indicates that approximately 2,000 daily northbound passengers use Tri-Rail on weekdays compared to 600 passengers on weekends. This represents an average vehicle occupancy of 280 passengers on weekdays and 170 on weekends. Similarly, 1,900 daily southbound passengers use Tri-Rail on weekdays compared to 550 passengers on weekends. This represents an average vehicle occupancy of 270 passengers on weekdays and 160 on weekends. The numbers are similar for both directions, indicating that transit users who use Tri-Rail for their morning commute to work also use Tri-Rail for their evening trip home. Daily VMT is approximately 70 train miles on weekdays and 35 train miles on weekends.

Table 2
Tri-Rail Transit Performance indicators
Average Daily Results

Type	Description	Northbound				Southbound			
		Weekdays		Weekends		Weekdays		Weekends	
		AM	PM	AM	PM	AM	PM	AM	PM
Measures of Quantity	**Person Throughput** (number of passengers)	756	1,222	194	409	1,091	792	290	262
	Vehicle Miles of Travel (train miles)	30	40	15	20	35	35	15	20
	Avg. Vehicle Occupancy (passengers per train)	126	153	65	102	156	113	97	66
Measures of Quality	**Average Travel Time** (minutes)	8	8	8	8	8	8	8	8
	Average Travel Speed (miles per hour)	38	38	38	38	38	38	38	38
	Density (passengers/seat; percent)	21%	26%	11%	17%	26%	19%	16%	11%
	Time Heavily Congested (percent)	0%	0%	0%	0%	0%	0%	0%	0%

Average travel time for the Tri-Rail trip along the corridor is 8 minutes, compared to an average travel time between 4 and 5 minutes for an automobile trip. The resulting average speed is approximately 40 miles per hour for the train, compared to an average speed between 65 and 75 miles per hour for an automobile. The density analysis indicates that between 19 and 26 percent of the train capacity is being utilized during weekdays, while percent utilization is only between 11 and 17 percent on weekends. As expected, the Tri-Rail tracks are never congested since all trains are scheduled with constant headway, indicating that there is no time during the day in which this transit system is heavily congested.

GENERAL IMPLICATIONS OF STUDY

The multimodal measures discussed earlier are considered suitable for evaluating the performance of corridors in small and medium-size areas. The selected quantity and quality measures are expected to provide sufficient information about the status of the transportation element being considered in these areas. In addition, these measures are flexible in terms of achieving the goals and objectives of potential users. For example, if the goal of city and local officials is to improve mobility in a small urban area by moving more people between different origins and destinations

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quickly, efficiently, and safely, corridor measures such as person throughput or average vehicle occupancy can be used for that purpose. Similarly, if the purpose is to quantify congestion along a major transportation corridor in a medium-size urban area to determine the location and nature of transportation problems, corridor measures such as average travel time, average travel speed, or density can be used. Finally, these measures are useful for evaluating corridor performance during different hours of the day, such as peak hours, off-peak hours, or an entire day.

However, a key concern regarding the application of performance measures in small and medium-size areas is the cost and method of data collection. This is because some measures may require new data that may be difficult or expensive to obtain, resulting in an extra financial burden on the smaller urban area where the competition for scarce tax or other revenue resources is high. As such, several important strategic inferences regarding data collection and system utilization can be made from this study.

- Transportation performance can be adequately determined using traditional data collection techniques. These include roadside observations, special traffic volume counts, or permanent count stations (TTMS sites) if available. In addition, transit databases should be utilized if available. Small and medium-size areas do not need to invest in new and expensive technology at this time to collect the required data. For example, the use of video cameras or infrared technology to collect vehicle occupancy information may prove to be costly for a small community. Such technologies should be monitored for potential applications in the future when their prices become more affordable. Alternatively, less expensive methods of data collection can be fully utilized. For example, the use of additional TTMS sites is expected to save data collection costs in the future. Also, working in conjunction with other agencies such as a state office in acquiring network data may help cut costs.

- HOV lanes save time. As such, small and medium-size areas in cooperation with county and state officials are encouraged to promote such services. These are particularly useful for "bedroom communities" near larger urban areas (satellite communities). Under these circumstances, an HOV lane in a medium-size community should encourage carpooling; thereby, reducing the overall cost of congestion to that community by eliminating the incremental costs of single-occupant vehicles on the road. The results presented in this paper verify that HOV lane utilization is higher than the utilization of an average general purpose lane.

- The cost of collecting travel time data in the field can be minimized by using spot speed as a surrogate to calculate the travel time measure (the results from this study indicate that the difference between spot speed and speed computed from travel time is small -- less than 10 percent). In this case, spot speed information can be obtained in conjunction with traffic counts at no extra cost, and used with roadway distances to calculate travel time. Borrowed police radar guns may also be an inexpensive way to collect spot speed data. Such methods are appropriate only under normal or slightly congested traffic conditions, since spot speed is negligible in stopped or severely congested conditions. As such, travel time data will still need to be collected in the field for situations of stopped traffic or severe congestion.

- The cost of collecting accurate and sufficient vehicle occupancy information should be an important element for determining the level of success of these multimodal measures in small and medium-size areas. This is because prior experience has shown that vehicle occupancy data is expensive to collect due to the intensive labor and setup effort involved, in addition to several other necessary supplementary costs. Particular savings in vehicle occupancy data collection can result from repeated observations at the same location.
- Vehicle occupancy should initially be collected for at least one full day, and then be followed by short counts of one to two hours during the morning and evening peak periods. This method is satisfactory because vehicle occupancy is site specific and dependent on localized conditions, and once a site has been calibrated by an all-day control count, short counts can be subsequently used. The two primary methods suggested for the collection of vehicle occupancy data in small and medium-size areas are the roadside/windshield observation and the carousel method (where roadside observation is not possible, the carousel method of observation is recommended). Many factors influence the results of the roadside/windshield observation method, including human fatigue, weather conditions, amount of daylight, traffic density and speed, vehicle mix, and site location. The primary advantages include simplicity, and the ability to obtain large and representative sample sizes. On the other hand, the primary disadvantages include high cost due to extensive use of labor (i.e., sampling methods are usually used), and the difficulty of necessary observation at high volume, high speed multilane sites. The carousel method of observation is particularly useful in locations with three or more lanes, with high speed traffic, and in locations where it is difficult to station a roadside observer. It has proven to be reliable, efficient, and cost effective for collecting vehicle occupancy. The primary advantage of this method includes the ability to accurately observe from a short distance the number of people in the front and back seats of each targeted vehicle. However, the primary disadvantage includes the potential for observers in different survey vehicles to collect duplicate data when the spacing between these vehicles is not well designed.

- Small and medium-size areas may need to select alternative strategic options that provide commuters with incentives to promote transit ridership. These incentives include promotional and/or permanent cash discounts; coupon books; improving service reliability, safety, and cleanliness; and the provision of sufficient park-and-ride facilities.

SUMMARY AND CONCLUSIONS

The purpose of this paper is to report on the testing of selected multimodal corridor performance measures for a small and medium-size area, including an evaluation of the amount and cost of required data. These measures are either based on corridor volume to indicate quantity of travel, or on time to indicate quality. Measures of corridor quantity include person throughput, vehicle miles of travel, and average vehicle occupancy. Measures of quality include average travel time, average travel speed, density, and percent time heavily congested. The measures have been selected based on an analytic procedure and a scoring function that have been described elsewhere [5,6].

The measures are applied to the 5-mile segment of I-95 in the City of Hollywood, located in southeast Florida. I-95 consists of eight general-purpose lanes and two HOV lanes that extend throughout the corridor in both directions. The corridor also contains a commuter train service (Tri-Rail) that is operated by the Tri-County Commuter Rail Authority. Tri-Rail runs parallel to I-95, and provides service to the public on weekdays as well as weekends.

Several types of highway and transit data were collected along the corridor. Highway data included traffic counts, travel speed, travel time, vehicle occupancy, and standard roadway service volume at congestion. Transit data included monthly ridership by station, travel direction, time of day, day of week, and run for a period of one full year (1996). It also included information about scheduled travel time for trains between stations during the same time period.

The multimodal measures are reported in relation to a set of unique spatial and temporal parameters that are consistent with guidelines for reporting multimodal performance, and are tailored to the amount of detailed data that is available for each mode. They were found to be suitable for evaluating the performance of corridors in small and medium-size areas. This is because the variety of proposed quantity and quality measures are expected to provide sufficient information about the status of the transportation element being considered in these areas. In addition, these measures are flexible in terms of achieving the goals and objectives of potential users, and for application during different times of the day.
One key concern regarding the application of these measures in small and medium-size areas is the cost and method of data collection. This is because some measures may require new data that may be difficult or expensive to obtain, resulting in an extra financial burden on the smaller urban area. Several inferences regarding data collection and system utilization are made from this study: 1) multimodal transportation performance can be adequately determined using traditional data collection methods; 2) HOV lanes save time, suggesting the need for providing such lanes in smaller areas; 3) the cost of collecting travel time data in the field can be minimized by using spot speed as a surrogate to calculate the travel time measure; 4) the cost of collecting accurate and sufficient vehicle occupancy data should be an important element for determining the level of success of these measures; 5) vehicle occupancy should initially be collected for at least one full day, and then be followed by short counts of one to two hours during the morning and evening peak hours (where roadside observation is not possible, the carousel method of observation is recommended); and 6) small and medium-size areas may need to select alternative strategic options that provide commuters with incentives to promote transit ridership.

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