U.S. Department
of Transportation
Federal Transit
Administration

Unsticking Traffic: When Transit Works, and Why

October 1994

An FTA Policy Paper

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Prepared for:
Federal Transit Administration
United States Department of Transportation

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U.S. Department
of Transportation

**Federal Transit
Administration**

Administrator

400 Seventh St., S.W.
Washington, D.C. 20590

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Dear Colleague:

I am pleased to provide you with a copy of the enclosed report, "Unsticking Traffic: When Transit Works, and Why." This report presents an application of the Urban Transportation Performance Monitoring System (UTPM), a customer-based analytical method for measuring the performance of transportation on an intermodal level. This system makes and reports its measurements in a way that enables decisionmakers to identify the kind of improvements that make people, and the economy, better off.

The Urban Transportation Performance Monitoring System recognizes and seeks to understand the role of customers in determining the success of transportation systems and technologies. It is based on the observation that, in certain "strategic" corridors where traffic congestion is high and a high-capacity transit (e.g., rail or busway) is available, the door-to-door travel times on both modes tend to equalize. This phenomenon is known as the "Mogridge-Lewis effect" after its primary investigators, Martin Mogridge and David Lewis. Under these conditions, an improvement in the higher-capacity transit mode results in a corresponding improvement in door-to-door highway travel times. Highway users may thus benefit more from an investment in transit than in additional highway capacity.

This system has potential uses in forming a part of the cost-benefit framework for empirical multimodal performance analysis and may be useful in implementing the National Transportation System (NTS). This report contains the results of selected corridor studies to evaluate the Mogridge-Lewis effect.

We look forward to working with the transportation industry as we refine the Urban Transportation Performance Monitoring System. If you have any questions regarding the contents of this report, please contact Charlotte Adams, Director, Office of Policy, at 202/366-4060.

Sincerely,

Gordon J. Linton

Gordon J. Linton

Enclosure

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Executive Summary

Customer satisfaction is critical to the success of transportation investments. Satisfaction depends on rapid door-to-door travel times, predictable and reliable transportation, convenience, comfort, security and safety. The Urban Transportation Performance Monitoring System (UTPM) is designed to expose what customers <u>actually</u> gain from roads, transit, sidewalks, bikeways, parking facilities and the interconnected aspects of the transportation system. UTPM makes and reports its measurements in a way that enables decision makers to identify the kind of improvements that make people, and the economy, better off.

SIGNIFICANCE OF UTPM'S CUSTOMER PERSPECTIVE

A customer emphasis in performance measurement is important for two reasons. One is to obtain direct, unfiltered information about how the quality of urban life for people and businesses is affected by transportation services and infrastructure. Does transit matter to people? In what way does a transit service or a road affect business? Who rides and who benefits? UTPM is a direct approach to these questions.

Secondly, a focus on customers reveals what it is about their inclinations and desires that shapes the way transportation investments of different kinds interact and change in the quality of urban living. UTPM measures personal mobility directly in a way that explains how customers' choices determine the success or failure of new transportation investments. UTPM recognizes and seeks to understand the role of customers in determining the success of systems and technologies. Consider an analogy:

> *When a supermarket is crowded, people head for the shortest check-out lane, ensuring that all lanes deliver more or less equal check-out times. When queues become too long, management's response is to open another register. Now suppose a new technology is introduced on one register that electronically scans and assesses the value of an entire grocery basket in a few seconds. No matter how long the queue gets customers get through it in five minutes. Customers flock to this "high-capacity" lane. This shift soon shortens the queues at conventional registers. When getting through a conventional lane drops below five minutes some begin to switch back. <u>All</u> lanes thus level out at five minutes. In trying to manage growth in the number of shoppers, management soon realize that the five-minute equilibrium prevails even if they open additional registers of the conventional sort; customers simply shift to conventional lanes until crowding drives-up their processing time to five minutes. Because of this customer behavior, <u>only improving the speed of the high-capacity lane will improve check-out performance overall!</u>*

When cities are crowded, commuters can affect urban transportation performance in the same way. Many urban highways, bridges and tunnels are congested enough to induce the search for alternative routes. A newly opened highway lane may temporarily speed up the other lanes until it too becomes congested. But what if the city has a high capacity rail system? Rail system schedules are largely insensitive to increased numbers of passengers. Thus subway and commuter rail services attract customers who would otherwise be motorists. Through a natural tendency to "optimize," motorists tend to favor transit over highways in such corridors to the point at which the difference in door-to-door travel times disappears. In London, England an "equilibrium" speed for door-to-door journeys took root over 50 years ago and has remained stubbornly the same ever-since. In any city where such an equilibrium has developed, the only way to improve the performance of urban transportation, including roads, is to add to the high capacity transit system. Whether the same is manifest in any American cities was one focus of UTPM in 1993/94 and is summarized below.

UTPM's approach is direct: It starts with what customers want from transportation in specific markets. In congested urban corridors, safe, short and predictable door-to-door travel time is the most precious benefit to most people. When transit, such as commuter train service, is expressly designed to out-perform auto travel in terms that matter most to customers (especially travel time), it can succeed. The "optimizing" behavior of urban dwellers thus leads to faster trips for <u>both</u> transit passengers and motorists.

Future applications of UTPM will involve other qualities people expect from transportation, such as a network of low-cost, basic mobility around the city or region. A UTPM, or Transit Performance Monitoring (TPM) approach will be applied in urban as well as rural areas to determine how transit works in performing that service for its customers, a service quite different from relieving traffic congestion.

UNSTICKING TRAFFIC: WHEN TRANSIT WORKS, AND WHY

In applying UTPM to congested urban corridors around the country, FTA is addressing the most pressing questions facing transportation policy today. One is the impact of rail transit on the performance of congested urban roads. The UTPM results (Summary Table 1) indicate that the level of transit service dictates road speeds in corridors where transit has a long-standing presence. There are enough people exploring alternative modal choices in these areas to establish the "supermarket effect" that makes rail transit the only effective policy lever for upgrading multimodal performance. UTPM has firmly documented the effect in New York City. In fact, the common observation about Manhattan -- that average journey times by road have remained the same for the last century (which is largely true), is the result of near-constant average door-to-door journey speeds by subway and the Long Island Railroad over the same period. Thus only better rail transit performance in New York will improve mobility in the City's transportation system overall (including door-to-door road speeds); rail transit has become the "pacing mode" of the transportation system. UTPM is now searching for other cities and urban corridors where this is the case.

In contrast, UTPM finds that newly-built rail transit systems do not assume this kind of profound role in the urban system -- not at least until they become fully integrated in the urban fabric. In some urban corridors, years may be required before sufficient numbers of people are motivated to try transit alternatives and thereby trigger the "supermarket effect" that positions transit in a system-pacing role. This is probably due to the stickiness of long-standing auto habits; to the fact that land-uses take generations to adjust to the point where enough transit stations and residences are near each other; and, in some cases, to the fact that roads are not actually congested enough to prompt the threshold level of switching between modes.

However, it is also reasonable to expect new high capacity transit systems in certain corridors to take root as the pacing mode very quickly (within one year). The minimum (or "threshold") conditions that give rise to the "supermarket phenomenon" for transit are (i) a sufficiently high level of highway congestion; (ii) a sufficiently high population density; (iii) a sufficiently high propensity among highway users to explore transit as a travel alternative; and, of course (iv) door-to-door transit travel times that are competitive with road-based trips. FTA is currently planning to use UTPM to explore new transit lines in Chicago and Washington DC where these conditions are suspected to be in place. These investigations will help quantify the three "threshold" values, with important implications for rail transit funding decisions in other urban areas.

In summary, UTPM indicates that investment in urban rail transit matters, profoundly, in cities with long-established rail systems. New-transit corridors will mold to transit in this fashion if certain conditions are in place, conditions that are being investigated and quantified now. High capacity investments elsewhere may require a much longer term view and this invokes questions of affordability and risk that must be considered in the planning process.

MOBILITY: ARE TRANSIT-DEPENDENT PEOPLE GETTING A FAIR DEAL

The UTPM reveals that transit customers can face more inconvenience than roadway customers but suffer less unpredictability in their journey times (Summary Table 2). If this trade-off occurred as a matter of free choice, policy-makers could conclude that some people simply value reliability highly enough to bear some inconvenience to obtain it -- mobility could thus be judged equal for all. Many transit users do not of course have a choice (due principally to low income) and thus the longer amounts of time they may be compelled to spend walking, waiting and changing vehicles (gaining "access") means that urban mobility can be inferior for poorer people.

Importantly, the "access time penalty" experienced by transit users is less prominent in cities with well-established rail systems. In New York, UTPM reports access times for subway and auto users that are not very different (Summary Table 2). In some newer rail cities on the other hand UTPM reports access times for transit passengers that are nearly three-times longer than those experienced by auto users. These differences stem naturally from the long-term evolution of land-use adjustments precipitated by transit systems in urban corridors. Although mass transit systems present clear evidence of driving up population densities and thereby reducing travel access times, such changes occur over many years, even decades. Thus new investments in transit must be nurtured and sustained over many years if they are to fulfill the promise they already deliver in established transit cities of providing more balanced levels of mobility for people of different means and socio-economic circumstances.

Evidence from UTPM: 1993

Summary Table 1: Door-to-Door Travel Times for Peak Journeys in the Queens-Manhattan Corridor, By Alternative Modes
(Average Travel Time, in Minutes)

	Subway	**LIRR**	**Auto-Bridge (Un-tolled)**	**Auto-Tunnel (Tolled)**
Total	70.8[1]	64.4[1]	63.9[1]	58.5
Trip Segment				
Access Segment	48.6	47.0	34.2	25.3
Line haul segment	22.2	17.4	29.7	33.2
Sample Size (number of door-to-door journeys)	119	75	87	87

[1] Indicates no difference in mean travel time at the 95% confidence level.

Source: Urban Transportation Performance Monitoring System

The subway, LIRR and auto via bridge (un-tolled) provide statistically equal average door-to-door travel times during the peak. The same trips by auto via tunnel are subject to a $3.00 toll. These trips enjoy statistically shorter travel times, indicating that a road price can produce routes with higher levels of service than competing, un-priced routes.

Summary Table 2: Door-to-Door Travel Time for Peak Journeys in the Four Corridors, by Alternative Modes

	Manhattan-Queens		Newark-Manhattan		El Cajon-San Diego		Midway-Chicago	
	Subway	Auto-Bridge	NJT-Ferry	Auto	Auto-Trolley	Auto	Bus	Auto
	Average Travel Time, in minutes:							
Access Segment	48.6	34.2	38.0	27.6	30.6	11.5	33.7	18.4
Line Haul Segment	22.2	29.7	48.3	31.0	36.9	12.1	27.4	20.0
Total	70.8	63.9	86.3	58.6	67.5	23.6	61.1	38.4
	Travel Time Reliability (Measured in terms of Standard Deviation in Average Travel Time, in minutes)							
Access Segment	17.7	12.9	11.4	13.6	8.0	3.4	11.4	5.7
Line Haul Segment	5.1	10.0	6.5	11.9	5.0	2.2	5.3	6.0
Total	18.6	16.4	12.3	17.1	9.0	3.9	11.7	7.4
	Number of Door-to-Door Journeys							
Sample Size	119	87	45	29	101	318	101	155

Source: Urban Transportation Performance Monitoring System

Summary Table 2 indicates that transit and auto average travel times and travel time reliability are statistically equal in the Manhattan-Queens corridor. The two modes are in equilibrium. Transit outperforms auto for both travel time and reliability in the line haul segment, but falls short of the auto mode in the portion of the trip that accesses the train station. Improvements to the transit access time and reliability, through reduced headways, better information dissemination about schedules and better connections (for bus access) would improve the equilibrium travel time within the corridor.

In the Newark-Manhattan corridor, transit offers 47 percent longer travel times, but 28 percent greater reliability. Many individuals value the predictability of journey time more highly than other aspects of the trip. This finding is thus significant as a basis for educating the corridor population about the advantages of transit. As with the Manhattan-Queens corridor, transit reliability is lowest for the access component of the trip, and improvements here would improve travel times and reliability for travellers within the corridor.

The remaining two corridors did not exhibit the presence of an equilibrium. Road congestion was not evident for the El Cajon-San Diego corridor, and thus the auto mode provided superior performance to transit in all respects. A high capacity mode did not exist for the Midway-Chicago corridor (the transit mode was express bus which shared roadway capacity with auto), and thus an equilibrium was not present. Again, auto provided superior performance in both travel time and reliability.

1

Purpose of the UTPM and Plan of the Paper

1.1 Introduction

Rapid population and job growth in major U.S. metropolitan areas have placed great demands on the national urban transportation system, undermining its central purpose to facilitate the movement of people, goods and services. The increased vehicle use associated with changing employment and job growth patterns has produced serious problems involving traffic congestion, pollution, safety, and energy consumption. Traffic congestion is regarded as the most serious concern among these areas.

Urban traffic congestion affects our lives more directly than any other transportation problem. In recent years, residents of major U.S. cities have come to regard congestion as one of their most serious problems[1]. Billions of hours are wasted every year in traffic jams that reduce economic productivity and limit the time available for leisure and recreation. Recent findings on traffic congestion suggest:

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[1] Downs, A., Stuck in Traffic - Coping with Peak Hour Traffic Congestion, Anthony Downs, Brookings, 1992.

- From 1975 to 1987, the share of peak-period miles traveled on interstate highways with volume-to-capacity ratios higher than 80 percent, jumped from 42 to 63 percent;

- In just two years, from 1985 to 1987, the rush hour traffic classified as congested by the Department of Transportation rose from 61 to 63 percent; and

- Throughout the 1980's, peak periods of traffic congestion became considerably longer.[2]

The social costs associated with traffic congestion are enormous. A Texas Transportation Institute Study estimated that the cost of congestion in 1988 exceeded $34 billion including just thirty-nine large urbanized areas of the United States. Time lost from delays accounted for 65% of this amount.[3]

Recent policy measures embodied in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 address the increasing congestion problems with new and unique approaches. One such approach is a multimodal performance measurement tool that addresses a given corridor's transportation problems by exploiting the comparative advantage of each transportation mode in a multimodal system to improve overall system mobility. This multimodal approach places the emphasis on evaluating system-wide performance and on developing multimodal solutions to urban transportation problems, as distinct from assessing the performance of individual modes in isolation. This shift to a multimodal approach is influenced by the fact that the performance of any given transportation mode is affected by the presence of other competing modes.

The stated goals and stipulations of the ISTEA make it imperative to monitor the performance of the urban transportation system and to understand the nature and source of the major transportation problems in a multimodal context. For instance, not only is the measurement, tracking, and management of traffic congestion currently one of the foremost strategic concerns of transportation planning, but it also explicitly addressed in Section 3 of the ISTEA with regard to transportation investment decisions. An effective tool to both measure and manage traffic congestion in a true multimodal context, therefore, is essential.

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[2] Small, K.A., Winston, C., and Evans, C.A., Road Work: A New Highway Pricing and Investment Policy, Brookings, 1989.

[3] Hanks, Jr., J.W., and Lomax, T.J., Roadway Congestion in Major Urbanized Areas, 1982-88, College Station, Texas Transportation Institute, 1990.

Our research indicates that the present level of data available on traffic congestion is inadequate. This data limitation reflects the considerable gap in existing data collection and monitoring systems.[4] Our work - the design and implementation of **Urban Transportation Performance Measurement System (UTPM)** - represents one step in closing the information gap between the currently available data and the essential information required for determining corridor performance in a multimodal setting. Using the UTPM, policy-makers will be able to adopt the optimum mix of policies that maximizes the performance of the urban transportation system for a given investment.

1.2 Development of UTPM

The UTPM system is a customer-oriented approach to measuring the mobility of people in urban America. It is designed not only to observe and describe mobility, but to also understand, explain, and forecast it. The UTPM allows for a comprehensive evaluation of urban transportation improvements and to determine whether they will enhance mobility. UTPM thus asks four basic questions about the performance of urban transportation:

Observation and description. What is the state of mobility in urban America?

Understanding and explanation. How, why and for whom is it changing?

Forecasting. How will performance change if certain policy options are adopted? and

Evaluation. What benefits and costs will arise from a change in performance?

The UTPM represents a systematic approach to the collection of travel-related data for all modes in an urban corridor over time. UTPM assists in analyzing corridor performance with a view towards identifying transportation problems and the prospective impact of different policy options and investments.

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[4] Arthur B. Sosslau, Surface Passenger Transportation Data Needs, Resources, and Issues, *Data Resources for National Transportation Decision Making*, Transportation Research Record No. 1253, 1990.

Specifically, the purpose of the UTPM system is four-fold:

- First, it identifies how urban transportation systems respond to the choices and preferences of individuals and it measures the quality of those responses;

- Second, it provides policy and decision-makers a standard and acceptable procedure to measure and monitor transportation system performance at regular intervals in order to assess the level of service that the system provides its users (measured as door-to-door travel time, mobility, and cost) over time.

- Third, it identifies changes in transportation trends that may suggest emerging problems or potential areas of opportunity and it establishes the supporting data necessary to evaluate the impacts of transportation system improvements, investments and policy decisions.

- Fourth, it measures specific improvements in the operational or technical performance of one transportation mode and the effect that it has on the performance of the entire transportation system.

As explained above, changes made to one mode will be likely to affect the performance of competing modes in the system. How the surface transportation system responds to such changes, and the conditions under which these effects occur is the subject of substantial research. The application of the UTPM system will provide the data necessary to appreciate the dynamics of these intermodal impacts and linkages.

1.3 Plan of the Paper

Chapter 2 presents the objectives of UTPM and describes what it measures and how it can assist in identifying interrelationships, if any, between modes on a given corridor. Previous empirical and theoretical evidence on the interrelationships between modes is also presented and the necessary conditions contributing to intermodal linkages are identified in this chapter. An overview of the UTPM experimental design and a description of the four corridors to which it was applied is described in Chapter 3. Chapter 4 presents the results of the application of the UTPM on the four corridors. Finally, Chapter 5 briefly explains the data analysis component of the UTPM system.

2

UTPM as a Multimodal Performance Measurement Tool

2.1 Objectives of the UTPM System

The Urban Transportation Performance Measurement (UTPM) System is a tool that provides practical information in a multimodal context to decision- and policymakers.

A well-designed UTPM system serves three important objectives:

- **To measure and monitor door-to-door multimodal performance**. The UTPM system provides periodic and detailed information on journey time and travel speed. This information enhances our understanding of how competing modes within a major urban corridor compare in terms of mobility, cost and other travel-related characteristics such as comfort, safety, convenience and security to the customer.

  The UTPM systems addresses typical concerns with regard to the measurement of multimodal performance, such as:

  - What is the share of access and common segment journey times as a proportion of total door-to-door journey time? How do these values vary over time and across modes?

  - Are there significant differences, for a given mode and corridor, in the values of mobility measures (such as door-to-door speed and travel time) between peak and non-peak traffic conditions? Does the same relationship hold true in other modes and corridors?

  - Are there significant differences between modes for a particular corridor with regard to mobility, comfort level, and costs? How does the high capacity mode compare to the other modes in these measures?

  - Do certain modes provide greater travel reliability as estimated by variability of door-to-door speed and travel time?

- **To examine intermodal linkages**. The UTPM data can assist transportation and urban policy decision-makers recognize the fundamental interrelationships between transportation modes in a given urban corridor. Recent empirical evidence from the United Kingdom suggests that modal performance is greatly influenced by the performance of other competing modes. Thus if there are two major competing and interrelated modes in a given corridor, one of which is a high capacity public transit system mode and the other is the auto mode, the possible effects of transit improvements at the system level include:

  - An increase in transit ridership;

  - A reduction in door-to-door journey travel times (increase in journey speeds) in transit for existing and new transit riders; and

  - A reduction in door-to-door journey travel times (increase in journey speeds) on roadways for existing auto users.

  These effects describe how transit improvements under certain conditions can prove to be beneficial to the entire transportation system.

  The UTPM system also assists in obtaining the most useful answers to many concerns regarding intermodal linkages. Typical concerns include:

  - Are door-to-door journey speeds for auto and transit similar in different corridors?

  - What are the sources of differences in door-to-door journey speeds between auto and transit among corridors?
  - How have door-to-door journey speeds for auto and transit changed over time?
  - Is there a discernible effect of public transit speed on road speed? As transit door-to-door speed increases, do auto door-to-door speeds also increase?

- **To isolate the impact of transportation policy options**. New policy options take the form of either supply-side or demand-side strategies. The supply-side strategy requires improvements that increase the carrying capacity of the transportation system. On the other hand, demand-side strategies involve, among others, measures which tend to reduce the demand for the transportation system during peak congestion periods. The impact of a given supply- or demand-side policy option can be assessed by analyzing the UTPM data.

  The UTPM system compares speed and travel time data both before and after transportation investments and it provides answers to the following concerns:

  - Do door-to-door journey speeds in transportation modes rise, fall or remain the same before and after a specific demand- or supply-side strategy is implemented ?
  - Is there a constant relationship between the improvements in the two transportation modes, and is this relationship affected by demand- or supply-side options? For instance, if the transit door-to-door journey travel improves by about x percent, by what percent (say y percent) does the auto door-to-door journey speed change? What is the relationship between x and y, i.e., whether $x = y$, $x > y$, or $x < y$?

2.2 The Theory Behind Intermodal Linkages

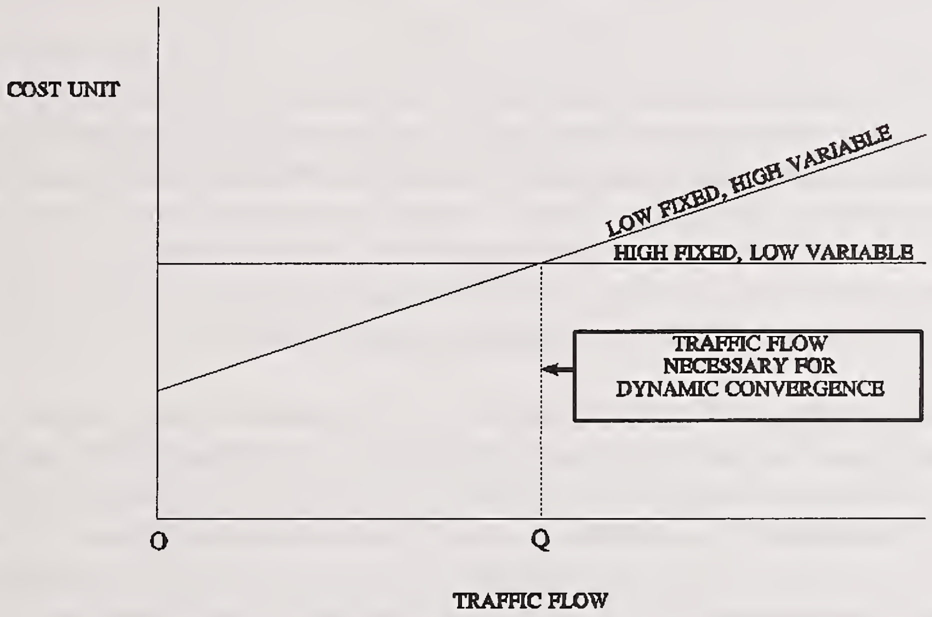
One of the principal objectives of UTPM is to provide an understanding of how competing modes are interrelated. UTPM data offers new insights on the performance of competing transportation modes and its conclusions can viewed in the context of available results of theoretical and empirical research. This section presents the results of previous theoretical and empirical work supporting the existence of intermodal linkages.

Our literature review supports the idea of travel equilibrium as a condition representing the convergence of the "attractiveness" of competing modes in a travel corridor. A transportation system consists of users who are constantly searching for better routes and modes, and it is in this sense a dynamic, continuously evolving system. One form of intermodal linkage corresponds to a situation where all modes converge to a travel equilibrium, at which point door-to-door travel speeds are equivalent among the modes. The equilibrium situation is therefore referred to as the case of dynamic convergence. However, previous research does not indicate the precise quantifiable relationship between the competing modes at equilibrium. Numerous hypotheses about the possible forms of relationships have been suggested by researchers. One such hypothesis is that the door-to-door journey speeds are equal for all competing modes in a particular corridor under specific conditions.

The premise of dynamic convergence suggests that travellers will choose the mode and route that minimizes their door-to-door travel cost. Total user costs include direct travel costs, travel time, and other intangible costs such as comfort, convenience and safety. When considering only the travel time component of the decision-making process, the convergence hypothesis states that when the door-to-door travel time of a particular mode changes relative to the competing modes, the pattern of travel on all modes adjusts so that the relative door-to-door travel times are once again in equilibrium. In the extreme case, travel times and associated speeds among competing modes may converge to the same value if all of the non-time costs among the modes are of equal value.

The early research relating to the convergence hypothesis focused on equilibrium between two competing roadways, each with a different cost function. Pigou (1920) and Knight (1924) were first to recognize the existence of an equilibrium situation based on the total cost per traveller on two competing roadways. Later Vickery (1969) further developed the ideas propounded by Pigou and Knight. He considered the situation where there were two roads serving the same potential trips, one in which the cost per additional traveller was very small but has high fixed costs, and the other has a cost per traveller increasing with the volume of travellers but low fixed cost (see Figure 2.1). Given this condition, Vickery argued that beyond the volume of traffic corresponding to the intersection of the two cost curves (point Q in the figure), the cost per traveller of using the road with the lower fixed costs is no longer dependent on the flow on it, but rather on the higher fixed costs of the road with the flat cost curve. Based on this principle, he argued against building of freeways in congested conditions.

FIGURE 2.1: ROADS/MODES WITH DIFFERENT COST CURVES



Downs (1962) was the first to extend this hypothesis to the examination of the competition between public transit and auto modes. His reasoning is similar to that of Knight and Pigou, and argues that when roads have an upward-sloping marginal cost curve, and public transit have a downward-sloping curve, an equilibrium between car and public transit costs would be established. At the equilibrium point, there will be travellers who would have the same costs by road as by public transportation, and who would be indifferent as to which of the two methods of travel they would use. Downs reasoned that if a very large number of people shift from transit to auto with the opening of a new roadway, the cost of transit per traveller may rise so that attractiveness of transit is reduced. Moreover, in this case the congestion on the new roadway may need to become slightly worse than before its construction before travellers switch back to transit since at equilibrium, automobile travel for some is just as desirable as transit. One of the conditions necessary to achieve this equilibrium is the existence of people for whom both rail and road are equally good, and who are constantly in search of better modes and routes to use.

The requirement of people to switch modes as a condition of dynamic convergence was also indicated in "The Surveys of Private Motoring in England and Wales" reported in Gray (1969). His survey results indicated that for equilibrium between modes to be established, a large proportion of travellers[5] had to be willing to switch modes over the course of time. Downs' conclusions are important in the context of major U.S. cities because he included examples from both Chicago and New York.

Thomson (1977) also recognized the phenomenon and concluded, "if the decision to use public or private transportation is left to the free choice of the individual commuter, an equilibrium will be reached in which the overall attractiveness of the two systems is about equal, because if one is faster, cheaper and more agreeable than the other there will be a shift of passengers to it, rendering it more crowded while the other become less so, until a position is reached where no-one on either system thinks there is any advantage in changing to the other."

Suchorzewski (1973 and 1976) also identified the phenomena but in terms of speed. He recognized the linkage between the efficiency of public transportation and the speed of a motor vehicle and concluded that the more rapid the public transportation, the higher the critical speed on the competing highway. His research, however, did not consider the impact of new road capacity on transit, but underscored the important role of public transportation in increasing network speeds.

Finally, based on traffic data in London over the last 50 years and on his own London survey on travel times on both rail and road, Mogridge (1987) concluded that average rail and road speeds have not changed much although car ownership had increased significantly. In his investigations he also determined that rail and road speeds are equal for trips of given distances within and around the central London conurbation and to central conurbations. Based on his findings he argued building new roads would not only have adverse effects on public transportation, but would ultimately reduce travel speeds for all modes. He concludes that it is the performance of the high capacity mode (the mode with the low slope marginal cost curve) in the urban transportation system that determines the performance of the overall system when all conditions for dynamic convergence are satisfied.

2.3 Conditions Contributing to Intermodal Linkages

Our review of the research indicates that a number of conditions contribute to the existence of intermodal linkages. The application of the UTPM on the four corridors not only established a "snap shot" of the performance of the

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[5] The survey completed over the period 1961-61 indicated that roughly 20% of household cars were used for part of the week suggesting that about 20% of commuter used a mixture of modes for work journeys. This group of people consisted of potential mode switchers.

transportation system in the corridor, but it also examined if there was any evidence of convergence. Of the corridors surveyed that *did not* portray the convergence of travel time and speed, at least one of the conditions identified below was not satisfied. However, for the corridors that *did* exhibit convergence, there was insufficient information available to determine whether all of the necessary conditions were evident (i.e. the proportion of travellers who switch between modes). If the research findings are accurate, one can only assume that all conditions existed for these corridors, although further research should be conducted to confirm this assumption. The conditions are briefly described below.

Existence of Competition Between Modes

People will change modes if they have a choice and if their choice increases their utility. While earlier research focused on a choice of roadways, the addition of public transportation only expands the number of options available to a road user; the same theory applies. Indeed, the research (Downs, Suchowreski) indicates that the dynamic convergence process is still valid involving both public transportation and road, and that competition between the modes attracts users from one mode to another.

Different Cost Functions for the Competing Modes

Previous research demonstrates that for convergence to occur the two transportation modes should exhibit different user cost characteristics. Cost, in this case, includes time related costs as well as direct costs. Public transit on dedicated guideways (i.e. light rail, subway) is generally regarded as the high-capacity mode whose performance is not adversely affected by increases in traffic. The road mode, on the other hand, has an upward-sloping marginal cost curve with increasing levels of traffic. These differences in the cost characteristics of the competing modes provide the incentive for road users to switch modes beyond a certain volume of traffic (and associated congestion). Such differences in cost characteristics on competing modes also explain why additions to road capacity may lower road speeds, and, in the extreme case, also worsen the performance of public transit.

Dominant Center Cities

The empirical evidence supporting the existence of dynamic convergence is based on studies in cities which have dominant central business districts. Thomson's conclusions on public transit and road equilibrium are relevant to those cities which either had a dominant center or were constructing major new facilities to enhance the dominance of the center.

City Size and Patterns of Employment

The city size and pattern of employment, which is partly affected by dominant city centers, also influences the demand for road travel and contributes to competition on modes. Research done by Smeed and Thomson suggests that in cities beyond a certain size and concentration, cars could not be used to provide all movement by individuals. Thomson concluded that "if the number of jobs in the city center exceeds 50,000 to 100,000, the use of cars for commuting normally becomes limited by lack of space."

High Levels of Car-ownership

Along with city size and density, increasing car ownership has been one of the major contributors to high levels of congestion in urban road systems. Travellers who choose not to use available cars to avoid congestion, (the suppression of demand) may motivate people to switch from road to public transportation.

Congestion Levels

The level of car ownership, city size and pattern of employment all contribute to the travel demand for the road network. The road system's inability to fulfill this potential demand leads to congestion, reduced travel speeds and increased travel time, forcing road travellers to seek other routes or modes. Research indicates that the existence of congestion on the roadway was a factor affecting the competition between modes and is a necessary condition for dynamic convergence.

Mode Switchers

Empirical evidence provided by Downs, Gray and Mogridge suggests that dynamic convergence can only occur when there are travellers who are prepared to seek and change to the mode which is potentially more attractive to them. This continual movement of travellers between modes and routes is a key factor in achieving dynamic convergence.

2.4 Policy Implications Based on UTPM Results

Chapter 4 presents the results of the application of the UTPM system on three national corridors. While the results appear to support the hypothesis that travel times across modes exhibit dynamic convergence provided the conditions identified above exist, they represent a measure of system performance for only one point in time. The measurement of system performance over time, however, more clearly demonstrates the effects of the dynamic convergence hypothesis.

The policy implications of the dynamic convergence of travel times are significant. Mogridge concludes, for example, that the speed of the road network is determined by the speed of the high capacity system (eg. a dedicated guideway system such as subway). Under these circumstances, increasing the capacity of road network may shift car-owning high capacity network users to the road system until road speeds are in equilibrium with the high capacity mode, resulting in excess capacity on the high capacity mode. If services are then reduced on the high capacity system, road speeds in equilibrium will be lower than before, and the performance of the entire system will have deteriorated. The dynamic convergence hypothesis suggests that the way to improve road speeds is to improve the performance of the high capacity mode in the system. Decisions ignoring such possible effects, therefore, are suboptimal.

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3

The Corridors Evaluated and Survey Design

3.1 The corridors studied

The UTPM system, developed as a component of this study, was applied to four corridors--Midtown Manhattan-Queens in New York City, Downtown Manhattan-Newark, San Diego-El Cajon and Chicago-Midway. The characteristics of each of these corridors are briefly described below.

3.1.1 The Midtown Manhattan-Queens Corridor

This study corridor, located in New York City, is approximately 12 miles in length and connects the Jamaica area of Queens, a predominately residential area, with the central business district (CBD) of Midtown Manhattan. The Manhattan zone is centered on Penn Station and extends for a radius of three quarters of a mile representing the average distance walked in 15 minutes. The Jamaica zone is defined by two points, each corresponding to the end stations of the two subway lines serving the corridor, the E line and the F line. All trip end points in the Jamaica zone are within a 15 minute drive distance from the two points.

Auto and subway are the predominate modes serving the corridor, comprising over 80 percent of the total trips made during weekdays. Subway is also considered the high capacity mode for this corridor. The remaining passenger trips are made on either the Long Island Railroad (LIRR) or express bus.

There are two major auto routes connecting Jamaica with Midtown representing the most direct routes. The first is the Long Island Expressway which crosses the East River with a toll tunnel (Queen-Midtown Tunnel) and the second is Queens Blvd which crosses the river at the Queensboro Bridge (toll-free). The auto-tunnel route is more direct but requires a $3.00 toll each way. Because of the different cost and time characteristics of these two routes, both were sampled in the survey and analyzed separately.

The subway system in New York City is very extensive and covers much of the city. The E and F lines were the subway lines used in this corridor. The E line runs from Jamaica Center to 8th Avenue in Midtown, at which point it turns south and continues to the World Trade Center. The F line begins at 179 Street in Jamaica, running parallel with the E line from Kew Gardens to 6th Avenue in Midtown. The specific line used was based on the proximity of the random trip end points to the subway line station. In some cases, where one line was preferred for one end point of a trip and the other line was better for the other, a transfer was made at the 71st and Continental Station.

Commuter rail operates six station within the corridor, but serves mostly trips with distances beyond the 12 mile corridor length studied here. However, for comparison purposes, it was included in the design and analysis of the corridor experiment. Table 3.1 presents several performance service characteristics of subway and LIRR in peak and no-peak flow directions.

Express bus was not included in the analysis since it provides limited service only in the peak direction and was not competitive with the other modes. A few sample trips also revealed higher travel times than those of the other modes, particularly since it has no dedicated lanes and, therefore, must share the road with auto users.

Bus and walking represented the access modes for public transit in the Jamaica zone, the particular mode employed being dependent on the trip end point's proximity to a transit station. For the Midtown Manhattan zone, it was assumed that all travellers using public transit walked to their final destination. This was corroborated with staff from the Metropolitan Transportation Authority and the MPO.

Table 3.1: PERFORMANCE AND SERVICE CHARACTERISTICS OF SUBWAY AND LIRR MODES IN NEW YORK CITY

Performance and Service Characteristics	Subway		Long Island Railroad	
	Peak[6]	Non-Peak	Peak	Non-Peak
Number of transit station stops in access segment (both ends combined)	12	12	5	5
Number of transit station stops in common segment[7]	7	7	2 to 4[8]	2 to 4
Approximate average headway range for access segment (minutes)	5 to 10	5 to 30	5 to 10	5 to 30
Approximate average headway for common segment (minutes)	3.9	8.3	4.7	10.3
Average Fare (one way without quantity discounts)	$1.25	$1.25	$4.50	$3.50

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[6] Peak refers to peak-flow trips in the peak period. Non-peak refers to non-peak period and also off-peak flow trips in the peak period.

[7] Common segment refers to the corridor segment which is common for all trips sampled on that mode. Number of transit stations on common segment include the stations at either end of the common segment.

[8] The number of stations for LIRR depends on the type of train service. since some trains offer skip-stop service.

3.1.2 The Downtown Manhattan - Newark Corridor

This study corridor joins the Millburn/Summit/Springfield area west of Newark, New Jersey, a predominately residential area, with the central business district (CBD) of Downtown Manhattan and is approximately 17 miles in length. The Downtown Manhattan zone covers the Financial District and is centered around the World Trade Center. Most of the trip endpoints are, again, within a 15 minute walk from the Trade Center, however there are few points that require use of the New York City Subway. The New Jersey zone borders Newark and is centered at the Short Hills Transit Station. All trips within the zone are within a 15 minute drive distance from this station.

Based on a passenger survey of interstate travel conducted by the Port Authority of New York and New Jersey, there are approximately 2,000 morning in-bound trips made between these zones. About 15 percent of these are auto, all of which access Downtown Manhattan via the Holland Tunnel (for which there is a $5 toll one way). Nearly two thirds of the trips use PATH (Port Authority Trans Hudson light rail transit), of which two thirds use New Jersey Transit (NJT) to connect with the Hoboken-WTC PATH line. Most of the other PATH riders drive to the Newark-WTC line, parking at either Harrison or Newark. About 15 percent use the ferry, almost all making a connection at Hoboken by NJT trains. There is essentially no bus service in this corridor.

Four predominate "modes" result from this travel pattern, with all but the auto mode not requiring a transfer to a different mode. The modes are auto, auto-PATH, New Jersey Transit-PATH and New Jersey Transit-Ferry.

The auto route follows route 78 through the Holland Tunnel. Passengers using the New Jersey Transit System connect at Hoboken to either PATH or to the Ferry into Downtown Manhattan. The PATH ends at the WTC and the ferry at Battery City Park. Auto-PATH trips connect at the Newark station.

Subway and walking represent the two access modes from PATH or ferry in the Downtown Manhattan zone. Auto and walking are the access modes in the Millburn/Summit/Springfield zone. Table 3.2 presents the service characteristics of NJT Transit, Path and Ferry.

Table 3.2: PERFORMANCE AND SERVICE CHARACTERISTICS OF NEW JERSEY TRANSIT, PATH AND FERRY

Performance and Service Characteristics	NJT Transit[9]		PATH		FERRY	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Number of transit station stops in access segment[10] (both ends combined)	4	4	1	1	1	1
Number of transit station stops in common segment[11]	3 to 9	3 to 9	2	2	2	2
Approximate average headway range for access segment[12] (minutes)	NA	NA	NA	NA	NA	NA
Approximate average headway for common segment (minutes)	6.4	20	4	9	6	17
Average Fare (one way without quantity discounts)	$4.50 [13]	$4.50	$1.00	$1.00	$2.00	$2.00

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[9] PATH appears on two competing modes: NJ Transit/PATH and Auto/PATH. For the Auto/PATH mode, travellers transfer at Newark station, and for the NJ Transit/PATH mode the transfer occurs at Hoboken. Headways are the same for PATH trains from/to Hoboken and Newark stations.

[10] Number of transit stations in access mode refer to stations in stations in both of the catchment areas. PATH and Ferry modes each have one access transit station in Manhattan, that being the end station.

[11] The number of transit stations available (inclusive of origin and destination stations) depend upon whether the service is regular or skip stop.

[12] There was no transit access mode such as bus for public transit.

[13] This is an approximate fare and the actual fare (without any discount) will depend on the departure station in New Jersey for eastbound trips and on how the ticket is bought (whether in-train or at the station).

3.1.3 The El Cajon - San Diego Corridor

This study corridor is approximately 13 miles in length and connects El Cajon, a suburb of San Diego, with the city's central business district (CBD). The El Cajon zone is centered at the El Cajon Trolley Station. Trip end points within the zone are no more than a 15 minute drive to the Trolley station. The downtown San Diego zone, centered on the Civic Center Trolley Station, extends for a radius of three quarters of a mile representing the average distance walked in 15 minutes.

Auto and the Trolley East line are the competing modes serving the corridor. Although there is limited express bus service on the corridor, its ridership represents less than five percent of the total ridership and was, therefore, deemed not to be competitive. The Trolley is the high capacity mode for this corridor.

The auto route connecting the two zones follows Interstate 94 through the Highway 125 interchange onto Interstate 8 which leads to downtown San Diego. This was determined to be the most direct route based on simulations conducted by the San Diego Association of Governments, the MPO for the region.

The East line, one of two trolley lines in San Diego, extends from El Cajon to downtown where it loops and connects with the South trolley line (which runs to the Mexican border). Bus, auto and walk are the access modes to the trolley station sampled in the El Cajon zone. Trip end points within a 10 minute walk used walk access, those beyond a 10 minute drive used auto access, and those in between employed a mixture of bus and auto depending on the end point's proximity to a bus route. From a 1990 regional on-board survey, 45 percent used auto to get to the trolley station, 30 percent used the bus, and 25 percent walked. All trolley users were assumed to walk to their final destination in the downtown zone.

Unlike either of the two New York area corridors, this corridor has a significant proportion of travellers who use auto to get to/from downtown San Diego (estimated to be 95 percent), with 42 percent of the trip work-related. The high auto use can be explained in part by the relatively uncongested roads leading into the city, the abundance of available parking and the low cost of parking. Of the trolley users, more than 40 percent have a car available.

Table 3.3 illustrates several performance service characteristics of the San Diego Trolley.

Table 3.3: PERFORMANCE AND SERVICE CHARACTERISTICS OF THE SAN DIEGO TROLLEY

Performance and Service Characteristics	Trolley	
	Peak	Non-Peak
Number of transit station stops in access segment[14] (both ends combined)	3	3
Number of transit station stops in common segment	13	13
Approximate average headway range for access segment (minutes)	30-60	30-60
Approximate average headway for common segment (minutes)	15	15
Average Fare (one way without quantity discounts)	$1.75	$1.75

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[14] The access mode is bus in the El Cajon zone.

3.1.4 Chicago/Midway Corridor

This study corridor is approximately 12 miles in length and connects the Midway Airport with the city's central business district (CBD). The Midway area is centered around the Midway Airport. Trip end points within the zone are no more than a 15 minute drive to the airport. The downtown Chicago zone, centered around the loop, extends for a radius of three quarters of a mile representing the average distance walked in 15 minutes.

Auto and Bus are the competing modes serving the corridor. There was no high capacity mode serving the corridor at the time the study was conducted.

The auto route connecting the two zones follows the Stevenson Highway (I-55) connecting to the Ryan or I-90/94 which leads to downtown San Diego. This was determined to be the most direct route based on discussions with the Chicago transportation agencies: CTA, CATS, Metra and PACE (commuter bus).

Several CTA bus lines were studied that originate in the Midway area and connect with downtown. The bus routes selected offer express service inbound (to the Central Business District) in the morning, and outbound in the afternoon. Non-peak flow bus trips were also sampled. Each express bus line utilizes the Stevenson Expressway and connects with a downtown city street, State street. On the Stevenson Expressway, bus and auto traffic share the same lanes; there are no dedicated guideways to accommodate the public transit mode. In the loop area, State street is not open to automobile travel. Local bus service and walk are the access modes to the express bus stops sampled in the Midway zone. Trip end points within a 10 minute walk used walk access, those beyond a 10 minute drive used local bus access. Most express bus users walked to their final destination in the downtown zone but a few trips required the use of an additional local bus line.

This corridor has a significant proportion of travellers who use auto to get to/from downtown Chicago. The high use of auto can be explained in part by the abundance of available and inexpensive parking.

Table 3.4 illustrates several performance service characteristics of the express bus service in the corridor.

Table 3.4: PERFORMANCE AND SERVICE CHARACTERISTICS OF THE CHICAGO EXPRESS BUS

Performance and Service Characteristics	Express Bus	
	Peak	Non-Peak
Number of transit stops in access segment (MIDWAY AREA)	12[15]	12-15[16]
Number of transit stops in access segment (DOWNTOWN AREA)	9[17]	9
Number of transit stops in common segment	6-8[18]	6-8
Approximate average headway range for access segment (minutes)	5-15	5-20
Approximate average headway for common segment (minutes)	NA[19]	NA
Average Fare (one way without quantity discounts)	$1.75	$1.75

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[15] In the Midway area, buses stop about every 2-3 blocks. The number of stops portrayed in this table is an estimate of all stops in this area.

[16] In the non-peak, express bus service is altered. Some of the lines do not operate and travellers must rely on local buses.

[17] In the Downtown area, the express bus stops on every corner.

[18] The common area is made up of highway and feeders. Prior to entering the highway, buses make stops every 2 -3 blocks. Stops occur after exiting the highway at about the same rate until the downtown loop area is reached (the access segment).

[19] Travellers remain on the same bus for the access and common segments.

3.2 The Survey Design

Data was collected over a period of three to four Tuesdays (Thursdays for the Queens -Midtown Manhattan corridor). The same day of the week was sampled to eliminate fluctuations in traffic patterns and volumes due to the day of week effects. More than one day of sampling was required to ensure a statistically adequate sample size and to minimize the effects of unusual or circumstantial conditions.

Random or hypothetical trips were sampled rather than actual trips to provide greater control over trip start and end locations, route used and user characteristics. The hypothetical trips were generated by identifying random trip end points in the zones on either end of the corridor and joining them so that trips alternated between the zones. To reduce the effects of potentially biasing any one mode from sampling just one or two trips whose end points coincidentally favor one mode over another (due to location), up to 16 trip end points were generated within each zone to yield up to 32 distinct trips. Survey crews were then required to conduct these trips in a specified sequence so that all distinct trips were sampled at least once for each mode. Trip start times, however, were random. That is, the start time, other than the first trip of the day, was determined by the time the previous trip was completed.

Each trip observation recorded information concerning time, cost, and other qualitative information such as comfort, convenience and degree of congestion. Specifically, information included:

- Trip Start Time.
- Arrival Time at Transit Station (for transit).
- Time Entered Vehicle.
- Entry and Exit Times within the common segment.
- Entry and Exit Mileage within the common segment.
- Time Exited Vehicle.
- Trip End Time.
- Congestion Levels.
- Seating Availability (for transit).
- Weather and Road Conditions.

4

Results from the Corridors Evaluated

The analysis results of the four corridors evaluated are presented in Sections 4.1 through 4.5.

The detailed tabular results are presented in the Annexes following the chapter. There are fifteen tables for each corridor. The Queens/Manhattan corridor results are portrayed on Tables 4A.1 through 4A.15, New York/New Jersey results are displayed on Tables 4B.1 through 4B.15, San Diego/El Cajon results are located on Tables 4C.1 through 4C.15 and results for the Chicago/Midway corridor are located on tables 4D.1 through 4D.15.

4.1 Summary of Corridor Results

This section describes some of the key results of the four corridors surveyed in this study. It also offers several general observations common to all corridors. Some of the highlights include:

- In three of the four corridors, (New Jersey-New York, San Diego-El Cajon and Chicago-Midway), the auto mode was significantly faster than the competing public transit modes. Based on our analysis, the long headways for the transit modes are the major contributing factor for the differences.

- When comparing peak with non-peak flow, the speed in the common segment remains virtually unchanged for the transit modes but varies considerably for the auto modes. Since transit modes rely on a schedule with predetermined stops along the route, the speed should be unaffected by traffic volumes and change only if service headways change. Automobile traffic however, will be affected by changes in congestion levels on the roadways between peak and non-peak periods causing speed levels to vary.

- For transit modes using dedicated guideways, the variability in travel time is less than the variability in travel time for the auto mode, yet for transit modes without dedicated guideways the reverse occurs. In the former case, transit is designed to operate on a planned schedule and is less affected by congestion. In the latter case, transit modes and auto compete for the same roadway where transit modes make scheduled stops resulting in longer trips.

- Generally, travelling in the peak flow is slower than travelling in the non-peak flow for auto due to the increased level of congestion. For the transit modes, the non-peak flow is generally slower due to the longer headways and the discontinuation of express service.

- Variability in travel time and speed is greater in the access segment of the door-to-door trip than the common segment for all modes due to the greater number of transfers in the access segment, with the corresponding variability in walk the wait times and the changing bus headways throughout the day.

The studies also provides an opportunity to examine any intermodal linkages, based on observations in one point of time. The analysis of the survey results reveals dynamic convergence of door-to-door travel time and speed in the Queens-Midtown Manhattan corridor between auto and public transit but not for the remaining three corridors.

In the Queens/Manhattan Corridor, the results show that in the peak flow individuals travelling by public transit, subway or LIRR, and individuals travelling by auto via the Queensboro bridge will arrive at their final destination in roughly the same amount of time and travelling at the same direct speed. These results suggest the possibility that there are intermodal linkages in this corridor, although it is unknown as to whether in fact all of the necessary conditions exist. The conditions that are satisfied include:

- The existence of competing travel modes including the existence of a high capacity mode (subway).
- The existence of a busy urban center in Midtown Manhattan in which numerous individuals commute to and from on a regular basis.
- The existence of congestion on the roadways along the corridor.

Moreover, the results involving travel by auto via the Queens-Midtown Tunnel shows that travel by the auto-tunnel mode is significantly faster than by travelling by auto via the Queensboro Bridge. It appears that the existence of a $3.00 toll discourages sufficient auto users from the route, thereby lowering the level of congestion and improving travel speeds relative to auto trips made over the bridge. Tunnel users are willing to pay this toll to reduce their travel time by an average of 10 minutes, or about 15 percent of their total journey time.

4.2 Statistical Reliability of the Results

Queens/Manhattan Corridor

For the Queens-Manhattan Corridor, trips were conducted on each of the selected modes during the peak period, 6:00-9:00 AM and 4:00-7:00 PM over five Thursdays. Sample observations were taken for both peak flow (trips to Midtown in the morning and to Jamaica in the evening) and non-peak flow (all remaining trips) conditions. In total, over 350 door-to-door trip observations were made on the four modes. Table 4.1a presents the sample sizes and confidence intervals for each mode at the 95 percent confidence level. A confidence interval of 10 percent at the 95 percent level indicates a 95 percent likelihood that the actual travel time will be within 10 percent of the travel time generated from the sample. From the table, it can be seen that given the sample size the confidence interval is within 10 percent for all modes except auto via tunnel, which yields an interval of 13 percent. The lower confidence level is a result of the greater variability in travel time within the sample for this mode relative to the other modes. The greatest reliability is realized for the subway mode as a consequence of both a larger number of observations and lower variability in travel time.

Table 4.1b presents the same information for travel speed. The trends are the same as found in the table for travel time, except the confidence is somewhat better. This is due to the elimination of the component of variability in travel time introduced by slight differences in trip distances among the observations (since travel speed is travel time divided by distance).

Table 4.1a:

QUEENS/MANHATTAN: SURVEY SAMPLE SIZE AND CONFIDENCE INTERVALS BY MODE AND TRAFFIC FLOW CONDITION
(For travel time at the 95% Confidence Level)

	MODE								
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL		TOTAL
	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size
Peak Flow	33	9.3%	21	9.1%	29	9.7%	40	12.3%	123
Non-Peak Flow	86	5.3%	54	6.3%	58	8.8%	47	13.1%	245
Total Trip	119	NA	75	NA	87	NA	87	NA	368

Table 4.1b:

QUEENS/MANHATTAN: SURVEY SAMPLE SIZE AND CONFIDENCE INTERVALS BY MODE AND TRAFFIC FLOW CONDITION
(For travel speed at the 95% Confidence Level)

	MODE								
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL		TOTAL
	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size
Peak Flow	33	6.6%	21	10.7%	29	10.3%	40	11.8%	123
Non-Peak Flow	86	4.8%	54	6.9%	58	7.9%	47	13.0%	245
Total Trip	119	NA	75	NA	87	NA	87	NA	368

Newark/Manhattan

For the Newark/Manhattan Corridor, over 150 door-to-door trips were made over three Tuesdays during the peak period, 6:00-9:00 A.M. and 4:00-7:00 P.M. Both the peak flow (trips to Downtown Manhattan in the morning and to Newark in the evening) and the non-peak flow were sampled. The results with the accompanying confidence levels in relation to travel time and travel speed are illustrated in Table 4.2a and Table 4.2b.

Again, the same pattern appears for this corridor as for the Queens/Manhattan Corridor -- greater reliability on the transit modes, and generally, greater reliability for travel speed than travel time.

Table 4.2a:

NEWARK/MANHATTAN: SURVEY SAMPLE SIZE AND CONFIDENCE INTERVALS BY MODE AND TRAFFIC FLOW CONDITION
(For travel time at the 95% Confidence Level)

MODE									
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO		TOTAL
	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size
Peak Flow	18	7.1%	24	6.1%	17	6.8%	19	14.0%	78
Non-Peak Flow	27	7.6%	26	6.9%	13	9.1%	10	25.3%	76
Total Trip	45	NA	50	NA	30	NA	29	NA	154

Table 4.2b:

NEWARK/MANHATTAN SURVEY SAMPLE SIZE AND CONFIDENCE INTERVALS BY MODE AND TRAFFIC FLOW CONDITION
(For travel speed at the 95% Confidence Level)

	MODE								
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO		TOTAL
	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size
Peak Flow	18	7.8%	24	6.1%	17	5.9%	19	11.7%	78
Non-Peak Flow	27	8.4%	26	5.9%	13	9.7%	10	18.8%	76
Total Trip	45	NA	50	NA	30	NA	29	NA	154

San Diego/El Cajon Corridor

Tables 4.3a and 4.3b presents the San Diego/El Cajon sample size and the accompanying confidence levels for travel time and travel speed, respectively. For San Diego, over 450 observations were made over three consecutive Tuesdays. The peak hours surveyed for this corridor were 6:00-9:00 AM and 3:30-6:30 PM.

Given the large number of door-to-door trip observations, especially for the auto mode, the reliability of the data for this corridor is quite high. Again, the reliability of travel speed is generally better than that of travel time for the reason provided earlier.

Table 4.3a:

SAN DIEGO/EL CAJON: SURVEY SAMPLE SIZE AND CONFIDENCE INTERVALS BY MODE AND TRAFFIC FLOW CONDITION
(For travel time at the 95% Confidence Level)

	MODE						
	AUTO/TROLLEY		BUS/TROLLEY		AUTO		TOTAL
	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size
Peak Flow	64	3.3%	20	6.1%	162	2.5%	246
Non-Peak Flow	37	4.2%	19	8.3%	156	2.4%	212
Total Trip	101	NA	39	NA	318	NA	458

Table 4.3b:

SAN DIEGO/EL CAJON: SURVEY SAMPLE SIZE AND CONFIDENCE INTERVALS BY MODE AND TRAFFIC FLOW CONDITION
(For travel speed at the 95% Confidence Level)

	MODE						
	AUTO/TROLLEY		BUS/TROLLEY		AUTO		TOTAL
	Sample Size	C.I.	Sample Size	C.I.	Sample Size	C.I.	Sample Size
Peak Flow	64	3.2%	20	7.2%	162	2.5%	246
Non-Peak Flow	37	4.0%	19	8.0%	156	1.9%	212
Total Trip	101	NA	39	NA	318	NA	458

Chicago/Midway Corridor

Tables 4.4a and 4.4b presents the Chicago/Midway sample size and the accompanying confidence levels for travel time and travel speed, respectively. The tables show the reliability associated with the 256 observations made over four consecutive Tuesdays. Since the variability in door-to-door journey is relatively low, the statistical reliability is quite high (usually within a 5% error). The peak hours surveyed for this corridor were 6:30-9:00 AM and 3:30-6:30 PM.

Table 4.4a:

CHICAGO/MIDWAY: SURVEY SAMPLE SIZE AND CONFIDENCE INTERVALS BY MODE AND TRAFFIC FLOW CONDITION
(For travel time at the 95% Confidence Level)

	MODE				
	BUS		AUTO		TOTAL
	Sample Size	C.I.	Sample Size	C.I.	Sample Size
Peak Flow	58	5.0%	89	4.0%	147
Non-Peak Flow	43	7.4%	66	5.7%	109
Total Trip	101	NA	155	NA	256

Table 4.4b:

CHICAGO/MIDWAY: SURVEY SAMPLE SIZE AND CONFIDENCE INTERVALS BY MODE AND TRAFFIC FLOW CONDITION
(For travel speed at the 95% Confidence Level)

	MODE				
	BUS		AUTO		TOTAL
	Sample Size	C.I.	Sample Size	C.I.	Sample Size
Peak Flow	58	5.0%	89	3.8%	147
Non-Peak Flow	43	7.9%	66	4.6%	109
Total Trip	101	NA	155	NA	256

4.3 Mean Travel Time and Travel Speed

Mean travel time and travel speed results are described for each of four corridors evaluated. The detailed tabular results are presented for each corridor at the end of the chapter.

Mean travel time is the average door-to-door time required to complete the trips sampled within the particular mode and peak flow condition. The analysis presents travel time in terms of its constituent components of walk, wait and in-vehicle, and by segment -- access or common. The component segment is that component of the corridor common to all trips for a given mode, regardless of trip end location. The access component is the remainder of the trip.

Mean travel speed is presented as two metrics: *Route Speed* and *Direct Speed.* Route speed is the average speed of travel along the path taken get from one trip end point to the other, and is derived by dividing the distance travelled along the trip's path by the time required to complete the trip. Direct speed is the average speed if the path were a straight line between the trip's origination and destination, and can be interpreted as a normalized measure of travel time since it removes variations in distance over the sample observations. It is also a better measure of accessibility or mobility of the transportation system than route speed since it accounts for a transportation network's degree of circuity. For example, suppose there were two paths between points A and B, one with a 20 percent greater route speed than the other (which has a series of stop lights), but with a 30 percent greater route distance (because it by-passes the stop lights). In this example, the route that minimizes travel time would be the one with the series of stop lights. It would also provide the highest direct speed. In other words, a high route speed does not do one much good if the road network has one going in circles. The ratio of route speed to direct speed also yields the trip's *route factor*, or its degree of circuity.

Both route and direct speeds are presented by segment, but not by component since it makes little sense to have a walk and wait speed.

Queens/Manhattan Corridor

The following observations about the corridor's mean travel time and speed can be made based on the results presented in Tables 4A.1 through 4A.3 in Annex 4A.

- As expected, walk and wait times are greater for transit than auto in all instances, while auto has a larger in-vehicle share of the total trip time.

Moreover, for transit, the access segment travel times are generally two to three times that of the common segment, whereas for the auto mode, the access and common segment times are similar in magnitude. Again, this latter point is expected, since most of the transfer and walk times in the transit mode occur at either end of the journey.

- For the subway mode, journey times do not reveal a major change in peak and non-peak flow conditions. However, for the LIRR, the total non-peak flow journey time is 25 percent greater than for the peak flow. This is because during the non-peak period, the LIRR makes fewer stops along the corridor, requiring a transfer to subway or bus for a portion of the journey, and it has a more than doubling of the average headway. The result is an 85 percent increase in the wait time and a 20 percent increase in-vehicle time. Since the subway lines follow the same route throughout the day, and have a relatively small increase in average headways, the wait and in-vehicle times are not dramatically different between the peak and non-peak flow.

- For the auto-bridge mode, total non-peak journey time increases by about 18 percent over the peak period. The bulk of the increase is due to the in-vehicle time. It was suggested by the Port Authority of New York that the increase in freight carriers in the non-peak period cause higher congestion levels and an increase in travel time on the Queensboro Bridge route.

- For the auto-tunnel mode, the total door-to-door journey time does not show a marked change from peak to non-peak periods, suggesting that the Midtown Tunnel experiences relatively constant levels of traffic throughout the day and in both directions.

- The auto-tunnel door-to-door mean travel time is lower than that for the auto-bridge in both the peak and non-peak periods. Individuals travelling via the tunnel pay $3.00 in each direction whereas those travelling via the bridge have no toll. The additional cost of using the tunnel to the traveller results in a higher level of congestion on the bridge than in the tunnel.

- For the common segment, the LIRR has the highest direct and route speeds in both the peak and non-peak periods among all of the modes. One reason for the LIRR having a greater speed than the subway is that the LIRR makes fewer stops along the Jamaica-Manhattan corridor than the subway. Both auto-bridge and auto-tunnel have the lowest direct speeds in the common segment, but the highest direct speeds in the access segment.

- The LIRR's average walk time is greater than the subway's average walk time. There are fewer LIRR stations along the corridor, requiring additional walk distance.

Newark/Manhattan Corridor

The following observations are made based on the results presented in Tables 4B.1 through 4B.3 in Annex 4B.

- The auto mode has a direct speed roughly 40 percent higher than the other three modes studied in this corridor. Since commuting by car in this corridor is very costly, public transit is preferred, and represents over 80 percent of the trips made along the corridor. As a result, the congestion on the road generally is low, although there is congestion at the Holland tunnel itself. Also, auto/PATH is 10-20 percent faster than the pure public transit modes due to the higher road speed for the auto component of the journey.

- The common segment travel times and speed for the NJT/Ferry and NJT/PATH are almost identical. The common segment is predominately made up of the NJT trains and, since both of these modes rely on the same mode of transportation, the common segment travel time and speeds should be very similar. On the other hand, the access segment reveals a slightly longer travel time for the NJT/Ferry mode, due in part to the longer headways for the ferry. Moreover, the ease of transfer between the transit modes that occurs in these two mixed modes may also explain part of this difference.

- The NJT/Ferry door-to-door travel time is almost 10 percent greater for the non-peak flow than for the peak flow period. The number of ferries available decreases during the non-peak period causing travelers to wait 35 percent longer. There are also marginal increases in walk and in-vehicle travel times.

- The auto and auto/PATH modes display higher speeds in the non-peak than the peak flow whereas the NJT/PATH speeds remain unchanged. Due to the decrease in congestion on the roads, travel by auto is quicker in the non-peak. For the transit modes, the longer headways in the non-peak typically lower travel speed.

San Diego/El Cajon Corridor

The following observations are based on the information contained in Tables 4C.1 through 4C.3 in Annex 4C.

- In the San Diego/El Cajon corridor, the auto mode is 3 to 4 times faster in both the non-peak and peak periods than trolley. There is relatively little congestion on the roads (none of the auto survey crew indicated any congestion during their journeys) and an average speed of about 50 mph was observed for the common segment and 19 mph for the access segment.

- The access travel time for the bus/trolley mode is 40-60 percent higher than that of the auto/trolley, even though the access distances are greater for auto/trolley (the trips with their end point furthest from the El Cajon trolley station were assigned to the auto mode). In addition, the walk and wait times for bus/trolley are almost double those of the auto/trolley. These results reveal the much poorer service provided by bus compared to auto, and the relatively little congestion on the local roads around the El Cajon station. Our sample observations indicated that those travellers relying on the bus and trolley must wait on average over 15 minutes during their journey. This is explained by the combination of 15 minute headways on the trolley, and the 30 to 60 minute headways for the buses accessing the trolley stations.

- The common segment speeds for auto/trolley and bus/trolley are almost equivalent since both modes rely purely on the trolley for this segment of the journey. The trolley speed is very similar for both the peak and non-peak periods reflecting the constant 15 minute headway throughout the day and no change in service (eg. skip-stop operations).

- There is a greater difference between route and direct speed for the transit modes than for the auto mode reflecting the more circuitous route for the transit modes.

Chicago/Midway Corridor

The following observations are based on the information contained in Tables 4D.1 through 4D.3 in Annex 4D.

- In the Chicago/Midway corridor, the auto mode is about twice as fast as the bus mode in both the non-peak and peak flows.

- For the bus mode, travellers spend between 30 and 40 percent of the total door-to-door trip time waiting for the bus and walking to their final destination. The long headways for the buses as well as the accessibility of the bus stops are the major contributing factors.

- For the auto mode, the access segment mean travel time is almost identical for the peak and non-peak flow but the common segment travel time is double for peak versus non-peak. The common segment is composed of highway travel whereas the access segment is composed of travel via city streets. The difference in travel time for the common segment demonstrates that the congestion level on the highway varies substantially between the two periods. The difference in speed between peak and non peak for the auto mode in the common segment also provides evidence of the change in congestion. Again, the speed level doubles when comparing peak with non-peak flow.

- For the bus mode however, the common segment travel time decreases by only about 18 percent between the peak and non-peak periods. For the bus mode, the common segment has two components, highway and city streets. The highway section accounts for roughly 67 percent of the distance in the common segment and the city street section accounts for the remaining 33 percent. The travel time for the city street section remains constant throughout the day due to the numerous traffic lights, other bus routes and pedestrian traffic. The travel time on the highway however, changes dramatically between peak and non-peak and accounts for the 18 percent decrease in travel time.

- There is approximately a 22 percent difference between the direct and route speeds for the bus mode and a 21 percent difference in the auto mode. Both modes rely on the Stevenson Expressway for 40 percent of the total trip length. Since the modes follow a similar travel pattern, the degree of circuitousness for each mode is very similar.

4.4 Variability in Travel Time and Travel Speed

Variability is a measure of the reliability of travel, and it is calculated for both travel time and travel speed. Travel time and speed variability is represented by two metrics: standard deviation and coefficient of variation. The coefficient of variation is a normalization of standard deviation since it the standard deviation divided by the mean, presented as a percent.

Generally, since travel speed removes the variability in travel time introduced by variations in trip distance, it will display a lower variability than travel time.

The results for variability are presented for each of the four corridors in turn as they were for the mean results. From the analysis several patterns emerge. For example, the auto mode typically yields greater variability than transit, especially for transit using dedicated guideways. This is the result of transit designed to operate on a planned schedule and the mode being affected less by congestion than auto. Also, travel time and speed on the access segment generally displays greater variability than that of the common segment. This is due to the greater variability in the walk and wait components of the journey which typically occur in the access segment.

The greatest variability of the total door-to-door trip time, in terms of standard deviation, originates from the in-vehicle component of the journey. This is because it also represents the greatest proportion of the total trip time. When the coefficient of variation is used to compare the variability among the trip components for transit, the greatest relative contribution to variability originates from the wait component of trip. Also, variability is typically greater in the non-peak than the peak flow for transit, due largely to the lower regularity in service and an associated increase in the wait variability.

Queens/Manhattan Corridor

The following observations are based on the results from the Queens/Manhattan Corridor presented in Tables 4A.4 to 4A.9 in Annex 4A

- Generally, door-to-door travel time and speed variability is greater for auto than for transit. The difference in variability is largely due to the fact that the auto mode is more likely to be affected by changes in weather, road conditions and congestion whereas transit follows a fixed schedule.

- Generally, the in-vehicle component of the travel time represents the greatest share of the standard deviation, but this is because it also represents the greatest share of the total door-to-door travel time. Using the coefficient of variation, the wait component of transit yields the greatest share of variability relative to its share of total travel time.

- The coefficient of variation in the wait time is higher for the non-peak than the peak for transit. The difference is most likely greater variability in the headways in the non-peak period in the case of transit.

- In the Queens/Manhattan corridor, the public transit modes reveal similar travel time coefficients of variation in peak and non-peak flows, suggesting transit offers similar levels of reliability.

- In all modes, the access segment contributes the majority of the total deviation in travel time for both peak and non-peak flows. Factors responsible include the varying access distances from the randomly selected points in the catchment areas and the changing bus headways throughout the day resulting in greater variability in wait times.

- The auto-bridge mode shows greater variability in the peak flow than the non-peak flow, again due to the additional freight activity during the non-peak flow. Auto-tunnel is the mode displaying the highest variability, due in part to the variability in the time required to pay the toll at the tunnel.

Newark/Manhattan Corridor

The observations below are based on the data presented in Tables 4B.4 to 4B.9 in Annex 4B.

- For the NJT/Ferry and NJT/PATH modes, roughly two thirds of the door-to-door travel time variability stems from the walk and wait components of the trip. For the auto/PATH mode, this drops to about half of the travel time. This is due to the reduced walk time for auto/PATH and the need for one less transfer to transit (with its associated wait times).

- In all modes, the variability in trip time and speed is greater for non-peak than peak flow. This due to the longer and more variable headways in the non-peak, in the case of transit, and to the additional non-commuter traffic, freight traffic and fewer toll booth collectors at the Holland Tunnel in the case of auto.

- For both the peak and non-peak flow, the auto mode reveals a greater variability in travel time than the transit modes. The transit modes follow a fixed schedule and are less likely to be affected by changes in weather, road conditions and congestion.

- The coefficient of variation for both the NJT/Ferry and the NJT/PATH modes increases between the peak and non-peak flow. Reviewing the access and common segment data reveals that for NJT/Ferry, the access segment coefficient of variation decreases in the non-peak flow while this increases for the common segment, but for NJT/PATH the reverse occurs. The above phenomena is due to several factors, including:

    a) Longer headways for the ferry in the non-peak period.
    b) Differences in distribution between regular and skip stop scheduling.
    c) The longer headway for the ferry as compared to the PATH during the non-peak period.
    d) Differences in transfer efficiencies from the NJT Trains to PATH or the ferry .

San Diego/El Cajon Corridor

The data presented in Tables 4C.4 to 4C.9 in Annex 4C is summarized below.

- The variability in door-to-door travel time and speed for auto travel decreases from the peak to the non-peak flow. The San Diego/El Cajon corridor experiences little congestion on the roads, particularly in the non-peak flow. As a result the variability should be lower for the non-peak flow.

- The variability in travel time is greater for the trolley mode, and especially for bus/trolley than for the auto mode, which is a reversal of the experiences from the two New York corridors. The auto mode experiences little to no congestion, resulting in a more predictable travel pattern.

- The auto/trolley and bus/trolley modes both experience a decrease in variability in travel time for the common segment from the peak to the non-peak flow condition. Since the service characteristics for the trolley do not change, there is no apparent explanation for this result. A reverse pattern is revealed for the access segment (i.e. greater variability in the non-peak), in particular for bus/trolley, reflecting the greater variability in the wait time component of the journey during this period.

- The coefficients of variation of travel time and travel speed show that relatively more variation occurs in the access segment than in the common segment for all modes, with the difference being greatest for transit. The common segment for auto is comprised of interstate highways, and for transit is entirely dedicated trolley. The access segment, however, is composed of city and suburban streets for auto and transfers and walk components for transit. Therefore, the common segment should experience less variation than the access segment.

- The variability in travel speed for the total trip for transit remains virtually unchanged between the peak and non-peak flows. Moreover, the variability is very low. The access segment possesses a higher standard deviation than the common segment indicating that the travel speed for the trolley remains consistent throughout the day.

Chicago/Midway Corridor

The data presented in Tables 4D.4 to 4D.9 in Annex 4D is summarized below.

- The variability in mean travel time and speed decreases for the auto mode from peak to non-peak periods. Dividing the variability into access and common segments reveals that the decrease in variation is predominately in the common segment, indicating the effect of congestion on travel variability.

- The results for the bus mode indicate that the variation in door-to-door travel time increases approximately 23 percent between peak and non-peak flow. The increase in the access segment is largely due to the changing bus headways resulting in greater variation in wait times. In the non-peak flow, travellers may need to make a bus transfer in the common segment due to reduced bus service.

- Variability in travel time is greater for the bus mode than the auto mode for both the peak and non-peak flow. The increased variability is due to the following:

a) The bus headways vary considerably causing large variations in wait times.

b) Different bus stop locations that require different walk times.

c) The travel time varies due to changing number of transfers throughout the day. Over 25 percent of the door-to-door bus trip sampled required 1 or more transfers.

d) Express buses that do not operate in the non-peak flow causing travellers to make additional bus transfers and/or rely on more localized bus service.

4.5 Significance of Differences in Mean Travel Time and Speed

Statistical analysis was performed to determine if significant differences exist in travel data across the modes and flow conditions, and whether such differences were a result of statistical error. Both differences between the mean travel time and the mean travel speed were assessed.

The analysis performed series of t-tests on the comparisons. The t-test is a recognized test to determine the significance of a particular hypothesis. In this case we are testing the hypothesis that two mean travel times (or speeds) are statistically the same given the underlying level of reliability of the sample data.

The tables in the annex represent pairwise comparisons -- peak versus non-peak flow and for each possible mode comparison. For each comparison the table presents a t-value corresponding to the 95 percent confidence level which determines whether the differences in means are statistically different at the 95 percent level. In other words, t-values of less than 2.1 indicate that there is a 95 percent chance that there is no significant difference in the means being compared. The last row of the table determines the confidence level necessary for the difference in means hypothesis to become statistically significant.

Queens/Manhattan Corridor

The observations below are summarized from Tables 4A.10 to 4A.15 in Annex 4A.

- LIRR was the only mode that displayed a significant difference in both travel time and speed between peak and non-peak flow conditions. Due to the longer headways and the existence of fewer stops along the LIRR route during the non-peak flow, door-to-door travel times between the peak and non-peak flow are significantly different.

- The significance of difference in peak and non-peak travel time for auto-bridge is also evident at the 95 percent level, but this significance does not appear in the travel speed due to the lower variability in the speed measure. The travel time difference is largely due to the effect of increased freight traffic in the non-peak flow.

- Both the subway and auto-tunnel mode revealed no significant differences in peak and non-peak mean travel time and speed. In other words, there is little difference in travelling by subway and auto tunnel in the two flows.

- The significance of difference in mean travel time between modes in the peak flow yields no significant differences in mean travel time for all mode-pair comparisons except subway vs. auto-tunnel. In other words, travel time in the peak is statistically the same for all modes except subway and auto tunnel. Travel in the peak flow by auto-tunnel is significantly less time consuming that travel by subway. As mentioned in section 4.2, the toll cost of travelling via the Midtown tunnel may be sufficient to discourage travellers not to chose this mode/route, resulting in less congestion for the mode. The results from the other comparisons provide evidence of the dynamic convergence theory described in Chapter 2.

- Differences in travel time comparisons for the non-peak flow yield slightly different results than for the peak. The difference between subway and auto-tunnel is no longer significant (likely due to the greater variability of travel time for auto-tunnel in the non-peak), and LIRR versus subway and auto-tunnel, as well as auto-tunnel versus auto-bridge have become significant. The LIRR yields these result in the non-peak because its travel time increases by 25 percent in the non-peak flow, whereas travel time for the other modes remain relatively constant (see also the differences in means test for peak versus non-peak).

Comparisons with the auto-tunnel mode yield significance in the non-peak since the mean travel time for this mode appears to increase less in the non-peak than either LIRR or auto-bridge, creating the difference that did not exist in the peak flow.

- The significance of differences in mean travel speed yields similar results as those generated for travel time, except that now all comparisons with the auto-tunnel mode yield a significant difference that did not exist for travel time. The reason for this is that travel speed has a lower variability, thus yielding significance that did not exist with travel time. Again, LIRR and subway show a significant difference in travel speed in the non-peak flow, for the same reasons that their mean travel times are significantly different.

Newark/Manhattan Corridor

The observations provided below are summarized from Tables 4B.10 to 4B.15 in Annex 4B.

- The door-to-door trip observations obtained for this corridor displayed no significant difference between peak and non-peak travel time at the 95 percent level.

- All comparisons of mean travel time with the auto mode display significant differences at the 95 percent level. All comparisons between the transit modes in the peak flow show no significant differences (NJT/PATH versus auto/PATH is on the border line of being insignificant at the 95 percent level). In the non-peak flow, only the pure transit modes show no significant difference in mean travel time. Clearly, travel by auto reveals a significant travel time advantage over transit, taking on average 25 minutes less. Moreover, Auto/Path takes roughly eight minutes less than travel by the pure transit modes.

- When reviewing the significance of difference in mean travel speed, the results are very similar to those generated by travel time. In most instances, due to the lower variability in travel speed, the differences are more significant that they were with mean travel time. Again, modes with auto components generate higher travel speeds. The only comparison that does not yield a significant difference is NJT/Ferry and NJT/PATH. This is largely due to the fact that a high portion of the trips sampled on the two modes occurs on the same portion of NJT.

San Diego/El Cajon Corridor

The following observation are based on the analysis presented in Tables 4C.10 to 4C.15 in Annex 4C.

- The auto and the auto/trolley mode produce significant differences in peak and non peak travel speed and travel time, although their means reveal very little difference, especially for auto. This is a result of the high statistical reliability afforded by the large number of auto trip observations.

- All mode comparisons displayed a significant difference in both travel time and travel speed, and in particular, comparisons made with the auto mode. Those modes involving auto had superior travel times and speeds than the bus/trolley mode. Moreover, due to the infrequent scheduling of access buses, the bus/trolley mode was significantly slower and more time-consuming than the auto/trolley mode.

Chicago/Midway Corridor

The following observation are based on the analysis presented in Tables 4D.10 to 4D.15 in Annex 4D.

- The bus mode experiences no significance of difference for mean travel time and mean travel speed in the peak and non-peak periods. In other words, at any point during the day it takes about the same amount of time to travel between downtown Chicago and the Midway area by bus.

- For the auto mode, both the door-to-door travel time and travel speed are significantly different between the peak and non-peak flow. The decrease in the congestion level in the common segment causes the non-peak flow to be significantly quicker.

- Comparing the bus and auto modes during peak and non-peak periods for travel speed and travel time produces significant differences. The auto mode is faster than the bus mode in all periods.

ANNEX 4.A- QUEENS/MANHATTAN CORRIDOR RESULTS

Table 4A.1a:

QUEENS/MANHATTAN: MEAN TRAVEL TIME BY MODE AND TRIP COMPONENT
(minutes per trip)

MODE								
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	12.2	11.2	17.9	16.1	4.1	4.8	1.8	2.9
Wait	9.0	10.0	11.3	21.1	0.0	0.0	0.0	0.0
In Vehicle	49.5	48.3	35.1	42.6	59.8	70.8	56.7	59.5
Total Trip	70.8	69.5	64.4	79.8	63.9	75.6	58.5	62.4

Table 4A.1b

QUEENS/MANHATTAN: MEAN TRAVEL TIME SHARE BY MODE AND TRIP COMPONENT
(%)

MODE								
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	17.3%	16.2%	27.8%	20.1%	6.5%	6.4%	3.1%	4.6%
Wait	12.8%	14.4%	17.6%	26.4%	0.0%	0.0%	0.0%	4.6%
In-Vehicle	69.9%	69.4%	53.4%	53.4%	93.5%	93.6%	96.9%	95.4%
Total Trip	100.0%	100.0 %	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4A.2a:

QUEENS/MANHATTAN: MEAN TRAVEL TIME BY MODE AND TRIP SEGMENT (minutes per trip)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	48.6	46.7	47.0	61.0	34.2	42.5	25.3	33.6
Common Segment	22.2	22.8	17.4	18.8	29.7	33.1	33.2	28.8
Total Trip	70.8	69.5	64.4	79.8	63.9	75.6	58.5	62.4

Table 4A.2b

QUEENS/MANHATTAN: MEAN TRAVEL TIME SHARE BY MODE AND TRIP SEGMENT (%)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	68.6%	67.2%	73.0%	76.5%	53.6%	56.2%	43.3%	53.9%
Common Segment	31.4%	32.8%	27.0%	23.5%	46.4%	43.8%	56.7%	46.1%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0 %

Table 4A.3a:

QUEENS/MANHATTAN: PEAK FLOW MEAN ROUTE AND DIRECT SPEEDS BY MODE AND TRIP SEGMENT
(mph)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Route	Direct	Route	Direct	Route	Direct	Route	Direct
Access Segment	7.8	4.0	7.2	3.6	7.4	5.0	11.5	9.0
Common Segment	22.6	21.8	28.4	27.4	19.1	17.6	17.6	16.9
Total Trip	12.4	9.7	13.0	10.2	12.3	10.5	14.6	13.2

Table 4A.3b:

QUEENS/MANHATTAN: NON- PEAK FLOW MEAN ROUTE AND DIRECT SPEEDS BY MODE AND TRIP SEGMENT
(mph)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Route	Direct	Route	Direct	Route	Direct	Route	Direct
Access Segment	7.7	4.0	6.2	3.3	7.3	4.6	10.2	7.9
Common Segment	22.8	22.0	27.2	26.2	17.6	16.2	22.2	21.4
Total Trip	12.5	9.8	11.0	8.7	11.2	9.2	14.6	13.1

Table 4A.4a:

QUEENS/MANHATTAN: STANDARD DEVIATION OF TRAVEL TIME BY MODE AND TRIP COMPONENT

(S.D. minutes)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	5.8	6.7	9.1	8.0	5.9	4.5	2.8	4.0
Wait	5.9	8.3	6.4	11.0	0.0	0.0	0.0	0.0
In-Vehicle	14.2	12.3	6.7	15.8	15.7	24.0	21.9	25.6
Total Trip	18.6	17.3	15.1	18.4	16.4	25.2	22.5	27.8

Table 4A.4b:

QUEENS/MANHATTAN: SHARE OF TRAVEL TIME VARIABILITY BY MODE AND TRIP COMPONENT

(%)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	22.2%	24.6%	40.9%	23.0%	26.9%	15.7%	11.4%	13.5%
Wait	22.9%	30.3%	28.9%	31.5%	0.0%	0.0%	0.0%	0.0%
In-Vehicle	54.9%	45.1%	30.2%	45.5%	73.1%	84.3%	88.6%	86.5%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4A.5a:

QUEENS/MANHATTAN: STANDARD DEVIATION OF TRAVEL TIME BY MODE AND TRIP SEGMENT
(S.D. minutes)

MODE								
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	17.7	14.9	15.6	17.8	12.9	18.4	12.8	18.2
Common Segment	5.1	6.5	2.3	5.5	10.0	13.7	13.4	16.9
Total Trip	18.6	17.3	15.1	18.4	16.4	25.2	22.5	27.8

Table 4A.5b:

QUEENS/MANHATTAN: SHARE OF TRAVEL TIME VARIABILITY BY MODE AND TRIP SEGMENT
(%)

MODE								
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	77.8%	69.5%	87.3%	76.4%	56.3%	57.3%	46.5%	51.9%
Common Segment	22.2%	30.5%	12.7%	23.6%	43.7%	42.7%	53.5%	48.1%
Total Trip	100.0 %	100.0%	100.0%	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Table 4A.6:

QUEENS/MANHATTAN: COEFFICIENT OF VARIATION OF TRAVEL TIME BY MODE AND TRIP COMPONENT (%)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	47.0%	59.8%	50.7%	49.7%	NA	NA	NA	NA
Wait	65.6%	83.1%	50.7%	51.9%	NA	NA	NA	NA
In-Vehicle	28.7%	25.6%	19.1%	37.1%	26.2%	34.0%	38.6%	43.0%
Total Trip	26.3%	24.8%	23.5%	23.1%	25.6%	33.3%	38.5%	44.5%

Table 4A.7:

QUEENS/MANHATTAN: COEFFICIENT OF VARIATION OF TRAVEL TIME BY AND TRIP SEGMENT (%)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	36.5%	41.4%	33.1%	29.1%	37.7%	43.2%	50.6%	54.1%
Common Segment	22.8%	28.7%	13.0%	29.2%	33.7%	41.4%	44.5%	58.6%
Total Trip	26.3%	24.8%	23.5%	23.1%	25.6%	33.3%	38.5%	44.5%

Table 4A.8a:

QUEENS/MANHATTAN: STANDARD DEVIATION OF TRAVEL SPEED BY MODE AND TRIP SEGMENT
(S.D. minutes)

MODE								
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	1.4	1.4	1.2	1.6	2.0	2.4	4.0	4.6
Common Segment	3.2	5.5	3.5	5.1	5.6	5.5	6.4	10.2
Total Trip	1.8	2.2	2.0	2.2	2.8	2.8	4.8	5.8

Table 4A.8b:

QUEENS/MANHATTAN: SHARE OF TRAVEL SPEED VARIABILITY BY MODE AND TRIP SEGMENT
(%)

MODE								
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	31.0%	20.5%	25.1%	23.7%	26.5%	30.4%	38.1%	30.8%
Common Segment	69.0%	79.5%	74.9%	76.3%	73.5%	69.6%	61.9%	69.2%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4A.9:

QUEENS/MANHATTAN: COEFFICIENT OF VARIATION OF TRAVEL SPEED BY MODE AND TRIP SEGMENT (%)

	MODE							
	SUBWAY		LIRR		AUTO - BRIDGE		AUTO - TUNNEL	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	35.0%	35.5%	32.7%	47.6%	40.9%	52.4%	44.0%	57.5%
Common Segment	14.5%	24.9%	12.7%	19.4%	31.9%	34.0%	38.1%	47.8%
Total Trip	18.5%	22.5%	20.0%	25.5%	27.2%	29.9%	36.8%	44.1%

Table 4A.10:

QUEENS/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN PEAK AND NON-PEAK MEAN TRAVEL TIME BY MODE

	MODE			
	SUBWAY	LIRR	Auto Bridge	Auto Tunnel
T-Value @ 95% Level	0.35	3.72	2.60	0.72
Significant @ 95% Level	NO	YES	YES	NO
Confidence Level When Significant	<50%	99%	99%	50%

Table 4A.11:

QUEENS/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN PEAK AND NON-PEAK MEAN TRAVEL SPEED BY MODE

	MODE			
	SUBWAY	LIRR	Auto Bridge	Auto Tunnel
T- Value @ 95% Level	0.19	2.86	1.97	0.11
Significant @ 95% Level	NO	YES	NO	NO
Confidence Level When Significant	<50%	99%	90%	<50%

Table 4A.12:

QUEENS/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL TIME BETWEEN MODES FOR THE PEAK FLOW

	MODE					
	SUBWAY vs. LIRR	SUBWAY vs. AUTO BRIDGE	SUBWAY vs. AUTO TUNNEL	LIRR vs. AUTO BRIDGE	LIRR vs. AUTO TUNNEL	AUTO BRIDGE vs. AUTO TUNNEL
T-Value @ 95% Level	1.39	1.55	2.56	0.10	1.21	1.16
Significant @ 95% Level	NO	NO	YES	NO	NO	NO
Confidence Level When Significant	80%	80%	99%	<50%	50%	50%

Table 4A.13:

QUEENS/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL TIME BETWEEN MODES FOR THE NON-PEAK FLOW

	MODE					
	SUBWAY vs. LIRR	SUBWAY vs. AUTO BRIDGE	SUBWAY vs. AUTO TUNNEL	LIRR vs. AUTO BRIDGE	LIRR vs. AUTO TUNNEL	AUTO BRIDGE vs. AUTO TUNNEL
T-Value @ 95% Level	3.30	1.60	1.60	1.02	3.66	2.52
Significant @ 95% Level	YES	NO	NO	NO	YES	YES
Confidence Level When Significant	99%	80%	80%	50%	99%	99%

Table 4A.14:

QUEENS/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL SPEED BETWEEN MODES FOR THE PEAK FLOW

	MODE					
	SUBWAY vs. LIRR	SUBWAY vs. AUTO-BRIDGE	SUBWAY vs. AUTO-TUNNEL	LIRR vs. AUTO BRIDGE	LIRR vs. AUTO TUNNEL	AUTO BRIDGE vs. AUTO-TUNNEL
T-Value @ 95% Level	0.92	1.28	4.21	0.41	3.37	2.90
Significant @ 95% Level	NO	NO	YES	NO	YES	YES
Confidence Level When Significant	50%	50%	99%	<50%	99%	99%

Table 4A.15:

QUEENS/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL SPEED BETWEEN MODES FOR THE NON-PEAK FLOW

	MODE					
	SUBWAY vs. LIRR	SUBWAY vs. AUTO BRIDGE	SUBWAY vs. AUTO TUNNEL	LIRR vs. AUTO BRIDGE	LIRR vs. AUTO TUNNEL	AUTO BRIDGE vs. AUTO TUNNEL
T-Value @ 95% Level	2.89	1.27	3.76	1.18	4.92	4.19
Significant @ 95% Level	YES	NO	YES	NO	YES	YES
Confidence Level When Significant	99%	50%	99%	50%	99%	99%

ANNEX 4B- NEWARK/MANHATTAN CORRIDOR RESULTS

Table 4B.1a:

NEWARK/MANHATTAN: MEAN TRAVEL TIME BY MODE AND TRIP COMPONENT
(minutes per trip)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	19.9	20.5	21.7	21.9	8.5	8.5	(1)	(1)
Wait	14.4	19.5	16.0	12.1	8.1	6.6	0.0	0.0
In-Vehicle	52.0	53.8	50.3	55.4	63.0	59.7	58.6	52.5
Total Trip	86.3	93.8	88.0	89.5	79.5	76.2	58.6	52.5

(1) walk time is included in the totals.

Table 4B.1b:

NEWARK/MANHATTAN: MEAN TRAVEL TIME SHARE BY MODE AND TRIP COMPONENT
(%)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	23.1%	21.9%	24.7%	24.5%	10.6%	13.0%	0.0%	0.0%
Wait	16.7%	20.8%	18.2%	13.6%	10.2%	8.6%	0.0%	0.0%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0 %	100.0 %	100.0 %
In-Vehicle	60.3%	57.4%	57.1%	62.0%	79.2%	78.4%	100.0 %	100.0 %

Table 4B.2a:

NEWARK/MANHATTAN: MEAN TRAVEL TIME BY MODE AND TRIP SEGMENT (minutes per trip)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	38.0	43.8	39.6	38.5	31.8	26.9	27.6	25.9
Common Segment	48.3	50.0	48.4	51.0	47.7	49.3	31.0	26.6
Total Trip	86.3	93.8	88.0	89.5	79.5	76.2	58.6	52.5

Table 4B.2b:

NEWARK/MANHATTAN: MEAN TRAVEL TIME SHARE BY MODE AND TRIP SEGMENT (%)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	44.1%	46.7%	45.0%	43.0%	40.0%	35.3%	47.1%	49.3%
Common Segment	55.9%	53.3%	55.0%	57.0%	60.0%	64.7%	53.0%	50.7%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0 %

Table 4B.3a:

NEWARK/MANHATTAN: PEAK FLOW MEAN ROUTE AND DIRECT SPEEDS BY MODE AND TRIP SEGMENT
(mph)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Route	Direct	Route	Direct	Route	Direct	Route	Direct
Access Segment	8.2	5.2	7.6	5.1	7.5	7.7	11.8	9.2
Common Segment	23.3	17.7	23.0	18.1	22.5	18.3	35.5	29.8
Total Trip	16.5	12.1	15.6	12.0	15.8	13.3	23.1	19.1

Table 4B.3b:

NEWARK/MANHATTAN: NON-PEAK FLOW MEAN ROUTE AND DIRECT SPEEDS BY MODE AND TRIP SEGMENT
(mph)

	MODE							
SEGMENT	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Route	Direct	Route	Direct	Route	Direct	Route	Direct
Access Segment	8.2	5.2	7.6	5.8	8.5	8.3	13.0	10.1
Common Segment	23.8	18.0	21.1	16.6	21.4	17.4	39.6	33.3
Total Trip	15.9	11.6	15.3	12.0	16.7	14.1	26.1	21.6

Table 4B.4a:

NEWARK/MANHATTAN: STANDARD DEVIATION OF TRAVEL TIME BY MODE AND TRIP COMPONENT
(S.D. minutes)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	8.5	9.3	7.5	14.6	7.7	7.6	0.0	0.0
Wait	8.1	13.7	8.8	8.1	5.1	3.7	0.0	0.0
In-Vehicle	9.7	12.7	7.5	7.5	9.5	9.8	17.1	18.8
Total Trip	12.3	17.9	12.8	15.4	10.6	11.6	17.1	18.8

Table 4B.4b:

NEWARK/MANHATTAN: STANDARD DEVIATION OF TRAVEL TIME VARIABILITY BY MODE AND TRIP COMPONENT
(%)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	32.2%	26.1%	31.6%	48.4%	34.4%	36.2%	0.0%	0.0%
Wait	30.9%	38.3%	37.1%	26.9%	22.9%	17.4%	0.0%	0.0%
In-Vehicle	36.9%	35.6%	31.3%	24.7%	42.7%	46.4%	100.0%	100.0%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4B.5a:

NEWARK/MANHATTAN: STANDARD DEVIATION OF TRAVEL TIME BY MODE AND TRIP SEGMENT
(S.D. minutes)

MODE								
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	11.4	11.8	8.1	15.1	16.5	7.6	13.6	14.6
Common Segment	6.5	11.6	10.0	4.6	8.6	7.5	11.9	7.3
Total Trip	12.3	17.9	12.8	15.4	10.6	11.6	17.1	18.8

Table 4B.5b:

NEWARK/MANHATTAN: SHARE OF TRAVEL SPEED VARIABILITY BY MODE AND TRIP SEGMENT
(%)

MODE								
SEGMENT	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	63.7%	50.3%	44.6%	76.8%	65.6%	50.3%	53.3%	66.7%
Common Segment	36.3%	49.7%	55.4%	23.2%	34.4%	49.7%	46.7%	33.3%
Total Trip	100.0%	100.0%	100.0 %	100.0%	100.0%	100.0%	100.0 %	100.0 %

Table 4B.6:

NEWARK/MANHATTAN: COEFFICIENT OF VARIATION OF TRAVEL TIME BY MODE AND TRIP COMPONENT
(%)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Walk	42.5%	45.6%	34.7%	66.8%	90.6%	77.1%	NA	NA
Wait	56.4%	70.4%	55.3%	67.0%	63.1%	56.1%	NA	NA
In-Vehicle	18.6%	23.7%	14.8%	13.5%	15.1%	16.4%	29.2%	35.9%
Total Trip	14.3%	19.1%	14.5%	17.2%	13.3%	15.3%	29.2%	35.9%

Table 4B.7:

NEWARK/MANHATTAN: COEFFICIENT OF VARIATION OF TRAVEL TIME BY MODE AND TRIP SEGMENT
(%)

	MODE							
SEGMENT	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	30.0%	26.9%	20.4%	39.2%	51.8%	28.2%	49.3%	56.3%
Common Segment	13.4%	23.2%	20.7%	9.0%	18.1%	15.2%	38.4%	27.3%
Total Trip	14.3%	19.1%	14.5%	17.2%	13.3%	15.3%	29.2%	35.9%

Table 4B.8a:

NEWARK/MANHATTAN: STANDARD DEVIATION OF TRAVEL SPEED BY MODE AND TRIP SEGMENT
(S.D. minutes)

MODE								
SEGMENT	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	1.9	2.2	1.7	1.8	3.0	2.4	4.6	4.5
Common Segment	2.2	5.9	3.7	1.35	4.2	2.6	8.7	7.1
Total Trip	1.9	2.5	1.7	1.7	1.5	2.3	4.6	5.8

Table 4B.8b:

NEWARK/MANHATTAN: SHARE OF TRAVEL SPEED VARIABILITY BY MODE AND TRIP SEGMENT
(%)

MODE								
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	46.4%	27.3%	31.4%	57.2%	41.8%	48.8%	34.6%	38.7%
Common Segment	53.6%	72.7%	68.6%	42.8%	58.2%	51.2%	65.4%	61.3%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4B.9:

NEWARK/MANHATTAN: COEFFICIENT OF VARIATION OF TRAVEL SPEED BY MODE AND TRIP SEGMENT
(%)

	MODE							
	NJT FERRY		NJT PATH		AUTO/PATH		AUTO	
	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak	Peak	Non Peak
Access Segment	36.8%	42.5%	33.3%	30.9%	36.8%	29.6%	50.4%	44.2%
Common Segment	42.5%	42.5%	20.5%	8.1%	22.8%	14.7%	29.3%	21.3%
Total Trip	15.7%	21.2%	14.6%	14.5%	11.6%	16.3%	24.3%	26.7%

Table 4B.10:

NEWARK/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN PEAK AND NON-PEAK MEAN TRAVEL TIME

	MODE			
	NJT FERRY	NJT PATH	AUTO/PATH	AUTO
T-Value @ 95% Level	1.65	0.36	0.82	0.85
Significant @ 95% Level	NO	NO	NO	NO
Confidence Level When Significant	80%	<50%	50%	50%

Table 4B.11:

NEWARK/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN PEAK AND NON-PEAK MEAN TRAVEL SPEED BY MODE

	MODE			
	NJT FERRY	NJT PATH	AUTO/PATH	AUTO
T-Value @ 95% Level	0.00	0.0[illegible]	1.00	1.21
Significant @ 95% Level	NO	NO	NO	NO
Confidence Level When Significant	<50%	<50%	50%	50%

Table 4B.12:

NEWARK/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL TIME BETWEEN MODES FOR THE PEAK FLOW

	MODE					
	NJT FERRY vs. NJT PATH	NJT FERRY vs AUTO/PATH	NJT FERRY vs AUTO	NJT PATH vs. AUTO/PATH	NJT PATH vs AUTO	AUTO/ PATH vs AUTO
T-Value @ 95% Level	0.44	1.74	5.68	2.32	6.26	4.47
Significant @ 95% Level	NO	NO	YES	YES	YES	YES
Confidence Level When Significant	<50%	90%	99%	95%	99%	99%

Table 4B.13:

NEWARK/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL TIME BETWEEN MODES FOR NON-THE PEAK FLOW

	MODE					
	NJT FERRY vs. NJT PATH	NJT FERRY vs AUTO/ PATH	NJT FERRY vs AUTO	NJT PATH vs. AUTO/PATH	NJT PATH vs AUTO	AUTO/PATH vs AUTO
T-Value @ 95% Level	0.94	3.73	5.99	3.01	5.54	3.49
Significant @ 95% Level	NO	YES	YES	YES	YES	YES
Confidence Level When Significant	50%	99%	99%	99%	99%	99%

Table 4B.14:

NEWARK/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL SPEED BETWEEN MODES FOR THE PEAK FLOW

	MODE					
	NJT FERRY vs. NJT PATH	NJT FERRY vs AUTO/PATH	NJT FERRY vs AUTO	NJT PATH vs. AUTO/PATH	NJT PATH vs AUTO	AUTO/PATH vs AUTO
T-Value @ 95% Level	0.20	2.17	6.07	2.67	6.35	5.09
Significant @ 95% Level	NO	YES	YES	YES	YES	YES
Confidence Level When Significant	<50%	95%	99%	99%	99%	99%

Table 4B.15:

NEWARK/MANHATTAN: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL SPEED BETWEEN MODES FOR THE NON-PEAK FLOW

	MODE					
	NJT FERRY vs. NJT PATH	NJT FERRY vs AUTO/PATH	NJT FERRY vs AUTO	NJT PATH vs. AUTO/PATH	NJT PATH vs AUTO	AUTO/ PATH vs AUTO
T-Value @ 95% Level	0.55	3.08	5.30	2.94	5.21	3.91
Significant @ 95% Level	NO	YES	YES	YES	YES	YES
Confidence Level When Significant	<50%	99%	99%	99%	99%	99%

ANNEX 4.C- SAN DIEGO/EL CAJON CORRIDOR RESULTS

Table 4C.1a:

SAN DIEGO/EL CAJON: MEAN TRAVEL TIME BY MODE AND TRIP COMPONENT

(minutes per trip)

MODE						
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Walk	6.8	6.8	12.5	11.4	(1)	(1)
Wait	10.0	8.1	15.8	16.9	0.0	0.0
In-Vehicle	50.8	48.9	51.4	52.5	23.6	22.2
Total Trip	67.6	63.5	79.8	80.7	23.6	22.2

(1) walk times for auto are negligible since survey crew were able to park their cars directly at the trip end point.

Table 4C.1b:

SAN DIEGO/EL CAJON: MEAN TRAVEL TIME SHARE BY MODE AND TRIP COMPONENT

(%)

MODE						
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Walk	10.1%	10.2%	15.7%	14.1%	0.2%	0.0%
Wait	14.7%	12.8%	19.8%	20.9%	0.0%	0.0%
In-Vehicle	75.2%	77.0%	64.5%	65.0%	99.8%	100.0%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4C.2a:

SAN DIEGO/EL CAJON: MEAN TRAVEL TIME BY MODE AND TRIP COMPONENT
(minutes per trip)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Access Segment	30.6	28.4	43.4	44.8	11.5	10.9
Common Segment	36.9	35.1	36.3	35.9	12.1	11.3
Total Trip	67.6	63.5	79.8	80.7	23.6	22.2

Table 4C.2b:

SAN DIEGO/EL CAJON: MEAN TRAVEL TIME SHARE BY MODE AND TRIP COMPONENT
(%)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Access Segment	45.3%	44.7%	54.4%	55.5%	48.7%	49.0%
Common Segment	54.7%	55.3%	45.6%	44.5%	51.3%	51.0%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4C.3a:

SAN DIEGO/EL CAJON: PEAK FLOW MEAN ROUTE AND DIRECT SPEEDS BY MODE AND TRIP SEGMENT
(mph)

	MODE					
SEGMENT	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Route	Direct	Route	Direct	Route	Direct
Access Segment	13.0	6.8	9.4	5.2	28.0	18.8
Common Segment	27.6	15.7	27.8	15.8	58.7	48.5
Total Trip	20.8	11.5	17.7	9.9	42.6	33.2

Table 4C.3b:

SAN DIEGO/EL CAJON: NON-PEAK FLOW MEAN ROUTE AND DIRECT SPEEDS BY MODE AND TRIP SEGMENT
(mph)

	MODE					
SEGMENT	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Route	Direct	Route	Direct	Route	Direct
Access Segment	14.3	7.6	8.7	4.8	29.2	19.8
Common Segment	28.7	16.3	28.1	15.9	61.9	51.1
Total Trip	22.0	12.2	17.4	9.8	44.9	35.1

Table 4C.4a:

SAN DIEGO/EL CAJON: STANDARD DEVIATION OF TRAVEL TIME BY MODE AND TRIP COMPONENT
(S.D. minutes)

MODE						
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Walk	7.7	4.3	6.4	4.3	0.3	0.0
Wait	4.9	4.3	7.7	11.6	0.0	0.0
In-Vehicle	6.0	6.2	6.0	12.2	3.9	3.3
Total Trip	9.0	8.1	10.5	14.0	3.9	3.3

Table 4C.4b:

SAN DIEGO/EL CAJON: SHARE OF TRAVEL; TIME VARIABILITY BY MODE AND TRIP COMPONENT
(%)

MODE						
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Walk	28.7%	29.0%	91.8%	15.2%	8.2%	0.0%
Wait	29.9%	29.0%	38.5%	41.3%	0.0%	0.0%
In-Vehicle	41.4%	41.8%	29.7%	43.5%	91.8%	100.0%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4C.5a:

SAN DIEGO/EL CAJON: STANDARD DEVIATION OF TRAVEL TIME BY MODE AND TRIP SEGMENT
(S.D. minutes)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Access Segment	8.0	8.5	10.9	13.5	3.6	3.4
Common Segment	5.0	2.3	2.7	2.3	2.2	2.2
Total Trip	9.0	8.1	10.5	14.0	3.9	3.4

Table 4C.5b:

SAN DIEGO/EL CAJON: SHARE OF TRAVEL TIME VARIABILITY BY MODE AND TRIP SEGMENT
(%)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Access Segment	61.7%	78.5%	79.9%	85.5%	61.9%	60.9%
Common Segment	38.3%	21.5%	20.1%	14.5%	38.1%	39.1%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4C.6:

SAN DIEGO/EL CAJON: COEFFICIENT OF VARIATION OF TRAVEL TIME BY MODE AND TRIP COMPONENT

(%)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Walk	68.6%	66.2%	50.8%	37.3%	NA	NA
Wait	49.0%	52.6%	49.1%	68.6%	NA	NA
In-Vehicle	13.3%	12.6%	11.6%	23.3%	16.4%	15.0%
Total Trip	13.3%	12.7%	13.2%	17.4%	16.4%	15.0%

Table 4C.7:

SAN DIEGO/EL CAJON: COEFFICIENT OF VARIATION OF TRAVEL TIME BY MODE AND TRIP SEGMENT

(%)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Access Segment	26.3%	29.8%	25.1%	30.2%	31.6%	31.2%
Common Segment	13.5%	6.6%	7.5%	6.4%	18.5%	19.3%
Total Trip	13.3%	12.7%	13.2%	17.4%	16.4%	15.0%

Table 4C.8a:

SAN DIEGO/EL CAJON: STANDARD DEVIATION OF TRAVEL SPEED BY MODE AND TRIP SEGMENT
(S.D. minutes)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Access Segment	2.0	2.5	2.5	1.4	7.5	8.0
Common Segment	1.7	1.0	1.1	1.0	8.1	10.2
Total Trip	1.5	1.5	1.5	1.6	5.3	4.3

Table 4C.8b:

SAN DIEGO/EL CAJON: SHARE OF TRAVEL SPEED VARIABILITY BY MODE AND TRIP SEGMENT
(%)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Access Segment	53.5%	71.4%	70.2%	57.2%	48.0%	44.0%
Common Segment	46.5%	28.6%	29.8%	42.8%	52.0%	56.0%
Total Trip	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4C.9:

SAN DIEGO/EL CAJON: COEFFICIENT OF VARIATION OF TRAVEL SPEED BY MODE AND TRIP COMPONENT
(%)

	MODE					
	AUTO/TROLLEY		BUS/TROLLEY		AUTO	
	Peak	Non-Peak	Peak	Non-Peak	Peak	Non-Peak
Access Segment	29.2%	32.6%	48.8%	28.2%	39.6%	40.5%
Common Segment	11.1%	6.1%	6.8%	6.4%	16.7%	20.0%
Total Trip	12.7%	11.9%	15.4%	16.7%	16.0%	12.3%

Table 4C.10:

SAN DIEGO/EL CAJON: SIGNIFICANCE OF DIFFERENCE IN PEAK AND NON-PEAK TRAVEL TIME BY MODE

	MODE		
	AUTO/TROLLEY	BUS/TROLLEY	AUTO
T-Value @ 95% Level	2.32	0.24	3.50
Significant @ 95% Level	YES	NO	YES
Confidence Level When Significant	95%	<50%	99%

Table 4C.11:

SAN DIEGO/EL CAJON: SIGNIFICANCE OF DIFFERENCE IN PEAK AND NON-PEAK TRAVEL SPEED BY MODE

	MODE		
	AUTO/TROLLEY	BUS/TROLLEY	AUTO
T-Value @ 95% Level	2.33	0.11	3.49
Significant @ 95% Level	YES	NO	YES
Confidence Level When Significant	95%	<50%	99%

Table 4C.12:

SAN DIEGO/EL CAJON: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL TIME BETWEEN MODES FOR THE-PEAK FLOW

	MODE		
	AUTO/TROLLEY vs. BUS/TROLLEY	AUTO/TROLLEY vs AUTO	BUS/TROLLEY vs. AUTO
T-Value @ 95% Level	4.68	37.70	23.68
Significant @ 95% Level	YES	YES	YES
Confidence Level When Significant	99%	99%	99%

Table 4C.13:

SAN DIEGO/EL CAJON: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL TIME BETWEEN MODES FOR THE NON-PEAK FLOW

	MODE		
	AUTO/TROLLEY vs. BUS/TROLLEY	AUTO/TROLLEY vs AUTO	BUS/TROLLEY vs. AUTO
T-Value @ 95% Level	4.93	30.59	18.11
Significant @ 95% Level	YES	YES	YES
Confidence Level When Significant	99%	99%	99%

Table 4C.14:

SAN DIEGO/EL CAJON: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL SPEED BETWEEN MODES FOR THE PEAK FLOW

	MODE		
	AUTO/TROLLEY vs. BUS/TROLLEY	AUTO/TROLLEY vs AUTO	BUS/TROLLEY vs. AUTO
T-Value @ 95% Level	4.39	47.49	43.37
Significant @ 95% Level	YES	YES	YES
Confidence Level When Significant	99%	99%	99%

Table 4C.15:

SAN DIEGO/EL CAJON: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL SPEED BETWEEN MODES FOR THE NON-PEAK FLOW

	MODE		
	AUTO/TROLLEY vs. BUS/TROLLEY	AUTO/TROLLEY vs AUTO	BUS/TROLLEY vs. AUTO
T-Value Level@ 95% Level	5.49	54.43	49.56
Significant @ 95% Level	YES	YES	YES
Confidence Level When Significant	99%	99%	99%

ANNEX 4.D- CHICAGO/MIDWAY CORRIDOR RESULTS

Table 4D.1a:

CHICAGO/MIDWAY: MEAN TRAVEL TIME BY MODE AND TRIP COMPONENT
(minutes per trip)

MODE				
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Walk	9.6	9.2	1.4	1.4
Wait	9.6	14.9	0.4	0.4
In Vehicle	42.2	35.8	37.0	25.9
Total Trip	61.1	60.0	38.4	27.2

Table 4D.1b

CHICAGO/MIDWAY: MEAN TRAVEL TIME SHARE BY MODE AND TRIP COMPONENT
(%)

MODE				
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Walk	15.3%	15.4%	3.6%	5.0%
Wait	15.6%	24.9%	3.6%	5.0%
In-Vehicle	69.0%	59.7%	69.0%	95.0%
Total Trip	100.0%	100.0%	100.0%	100.0%

Table 4D.2a:

CHICAGO/MIDWAY: MEAN TRAVEL TIME BY MODE AND TRIP SEGMENT (minutes per trip)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Access Segment	33.7	36.7	18.4	16.9
Common Segment	27.4	23.2	20.0	10.4
Total Trip	61.1	60.0	38.4	27.2

Table 4D.2b

CHICAGO/MIDWAY: MEAN TRAVEL TIME SHARE BY MODE AND TRIP SEGMENT (%)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Access Segment	55.2%	61.3%	48.0%	61.9%
Common Segment	44.8%	38.7%	52.0%	38.1%
Total Trip	100.0%	100.0%	100.0%	100.0%

Table 4D.3a:

CHICAGO/MIDWAY: PEAK FLOW MEAN ROUTE AND DIRECT SPEEDS BY MODE AND TRIP SEGMENT
(mph)

	MODE			
	BUS		AUTO	
	Route	Direct	Route	Direct
Access Segment	10.2	8.1	17.4	14.1
Common Segment	16.0	13.3	22.5	19.0
Total Trip	12.5	10.1	19.2	15.9

Table 4D.3b:

CHICAGO/MIDWAY: NON- PEAK FLOW MEAN ROUTE AND DIRECT SPEEDS BY MODE AND TRIP SEGMENT
(mph)

	MODE			
	BUS		AUTO	
	Route	Direct	Route	Direct
Access Segment	9.6	7.8	18.5	15.1
Common Segment	18.9	15.7	44.6	37.6
Total Trip	12.9	10.6	27.2	22.6

Table 4D.4a:

CHICAGO/MIDWAY: STANDARD DEVIATION OF TRAVEL TIME BY MODE AND TRIP COMPONENT
(S.D. minutes)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Walk	5.5	5.1	1.2	1.1
Wait	[illegible]	10.6	0.0	6.3
In-Vehicle	8.0	7.2	7.4	6.3
Total Trip	11.7	14.4	7.4	6.3

Table 4D.4b:

CHICAGO/MIDWAY: SHARE OF TRAVEL TIME VARIABILITY BY MODE AND TRIP COMPONENT
(%)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Walk	23.8%	22.2%	14.4%	14.6%
Wait	39.0%	46.3%	0.0%	0.0%
In-Vehicle	37.2%	31.5%	85.6%	85.4%
Total Trip	100.0%	100.0%	100.0%	100.0%

Table 4D.5a:

CHICAGO/MIDWAY: STANDARD DEVIATION OF TRAVEL TIME BY MODE AND TRIP SEGMENT
(S.D. minutes)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Access Segment	11.4	12.9	5.7	4.6
Common Segment	5.3	6.2	6.0	4.2
Total Trip	11.7	14.4	7.4	6.3

Table 4D.5b:

CHICAGO/MIDWAY: SHARE OF TRAVEL TIME VARIABILITY BY MODE AND TRIP SEGMENT
(%)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Access Segment	68.1%	67.4%	48.6%	51.7%
Common Segment	31.9%	32.6%	51.4%	48.3%
Total Trip	100.0%	100.0%	100.0%	100.0%

Table 4D.6:

CHICAGO/MIDWAY: COEFFICIENT OF VARIATION OF TRAVEL TIME BY MODE AND TRIP COMPONENT
(%)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Walk	58.9%	55.0%	89.2%	79.4%
Wait	94.7%	70.8%	NA	NA
In-Vehicle	20.5%	20.1%	19.9%	24.4%
Total Trip	19.2%	23.9%	19.2%	23.3%

Table 4D.7:

CHICAGO/MIDWAY: COEFFICIENT OF VARIATION OF TRAVEL TIME BY AND TRIP SEGMENT
(%)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Access Segment	33.7%	35.0%	30.8%	27.0%
Common Segment	19.4%	26.8%	30.0%	40.9%
Total Trip	19.2%	23.9%	19.2%	23.3%

Table 4D.8a:

CHICAGO/MIDWAY: STANDARD DEVIATION OF TRAVEL SPEED BY MODE AND TRIP SEGMENT
(S.D. minutes)

MODE				
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Access Segment	2.8	3.3	4.0	4.0
Common Segment	3.3	2.8	5.4	10.1
Total Trip	1.9	2.7	2.8	4.2

Table 4D.8b:

CHICAGO/MIDWAY: SHARE OF TRAVEL SPEED VARIABILITY BY MODE AND TRIP SEGMENT
(%)

MODE				
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Access Segment	46.0%	54.2%	42.8%	28.1%
Common Segment	54.0%	45.8%	57.2%	71.9%
Total Trip	100.0%	100.0%	100.0%	100.0%

Table 4D.9:

CHICAGO/MIDWAY: COEFFICIENT OF VARIATION OF TRAVEL SPEED BY MODE AND TRIP SEGMENT
(%)

	MODE			
	BUS		AUTO	
	Peak	Non Peak	Peak	Non Peak
Access Segment	34.3%	42.4%	28.5%	26.3%
Common Segment	24.6%	17.9%	28.2%	27.0%
Total Trip	19.0%	25.8%	17.9%	18.8%

Table 4D.10:

CHICAGO/MIDWAY: SIGNIFICANCE OF DIFFERENCE IN PEAK AND NON-PEAK MEAN TRAVEL TIME BY MODE

	MODE	
	BUS	AUTO
T-Value @ 95% Level	0.43	10.14
Significant @ 95% Level	NO	YES
Confidence Level When Significant	<50%	99%

Table 4D.11:

CHICAGO/MIDWAY: SIGNIFICANCE OF DIFFERENCE IN PEAK AND NON-PEAK MEAN TRAVEL SPEED BY MODE

	MODE	
	BUS	AUTO
T- Value @ 95% Level	1.02	11.08
Significant @ 95% Level	NO	YES
Confidence Level When Significant	50%	99%

Table 4D.12:

CHICAGO/MIDWAY: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL TIME BETWEEN MODES FOR THE PEAK FLOW

MODE	
	BUS vs. AUTO
T-Value @ 95% Level	13.17
Significant @ 95% Level	YES
Confidence Level When Significant	99%

Table 4D.13:

CHICAGO/MIDWAY: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL TIME BETWEEN MODES FOR THE NON-PEAK FLOW

MODE	
	BUS vs. AUTO
T-Value @ 95% Level	14.09
Significant @ 95% Level	YES
Confidence Level When Significant	99%

Table 4D.14:

CHICAGO/MIDWAY: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL SPEED BETWEEN MODES FOR THE PEAK FLOW

MODE	
	BUS vs. AUTO
T-Value @ 95% Level	14.73
Significant @ 95% Level	YES
Confidence Level When Significant	99%

Table 4D.15:

CHICAGO/MIDWAY: SIGNIFICANCE OF DIFFERENCE IN MEAN TRAVEL SPEED BETWEEN MODES FOR THE NON-PEAK FLOW

MODE	
	BUS vs. AUTO
T-Value @ 95% Level	17.89
Significant @ 95% Level	YES
Confidence Level When Significant	99%

5

The UTPM Analysis Model

5.1 How the UTPM Analysis Model Works

The UTPM analysis model facilitates the survey data entry process and generates the tables presented in Annex 4. The model framework utilizes both a database program (PARADOX) and a spreadsheet program (LOTUS 1-2-3).

5.1.1 The Database Program (PARADOX)

The completed transportation surveys are divided between auto and transit modes. Each set of surveys are assigned a reference number. The survey data is entered into one of the database program templates. Separate database templates are used to enter the direct and route distance numbers for the various modes.

Upon completion of the data entry, an automated database program or "PAL" is activated which performs numerous calculations on the data. These calculations include:

- Wait, Walk and In-Vehicle Times
- Access and Common Segment Times
- Route and Direct speeds for the Access and Common Segments
- Number of Transfers per Trip

Finally, the database is checked for errors.

5.1.2 The Spreadsheet Program (LOTUS 1-2-3)

The user calls up the Lotus Spreadsheet template. A program menu appears at the top of the screen allowing the user to chose among several menu items or functions.

Through the use of the NAMES function, the user assigns the corridor and each transit mode a name. The user also defines the morning and evening peak periods.

By activating the AUTO option the spreadsheet queries the database containing the auto data. The TRANSIT function queries the database transit program. The data is separated into evening and morning and peak and non-peak. Additionally, the transit data is separated into the various transit modes. Summary table are generated with the following measures:

1) Mean values of travel time and speed by trip component and segment, and relative shares of travel times.
2) Measures of variability in travel time and speed, including the relative share of variability by trip component and segment.
3) Measures of significance in differences in means of travel time and speed between modes and peak/non-peak flow conditions.
4) Qualitative measures of convenience and comfort.

A RESET function allows the user to redo the AUTO and TRANSIT menu options.

A PRINT option prints the summary tables. (Note copies of the summary tables are located for each corridor in the Annex to section 4.)

A QUIT option ends the spreadsheet program.

5.2 The Cost of implementing the UTPM Survey

The cost of implementing the UTPM consists of three parts: planning the survey, testing the survey, conducting the survey and analyzing and reporting the results. Through the development of specialized tools (such as the UTPM analysis model), software purchases (such as KeyMap to assist in the generation of trip directions), and streamlining procedures, the first time costs of implementing the UTPM system in a corridor have been reduced significantly.

Planning and initiating the survey requires approximately 5 days, which include preliminary data collection and analysis and meetings with local transportation authorities (MPO and transit authorities). Approximately 8 days are required preparing the survey kits, recruiting the survey crew and arranging the survey particulars. The estimated time costs of planning the survey is $8,000.

Prior to conducting the survey itself, the direction trip kits need to be tested. The testing requires roughly 2 work days for the administrator of the survey and a student guide. This represents about $1,000.

The survey should be performed over several weeks, with the number of survey crew dependent on the required number of observations (which is a function of travel time variability), the number of modes to sample, and the number of observations possible per crew in a survey day. Total survey crew time and expenses are approximately $5,000 to $10,000. The administrator time is 2 to 3 days, resulting in a total estimated cost of survey execution of $7,000 to $12,000.

Data must then be coded and entered into the UTPM analysis model and tables generated and analyzed. This is expected to consume about 5 days of a work for an office assistant and 4 days for the consultant to review the data entry and generate the tables in the model resulting in an estimated cost of $2,500.

The total cost of implementing the survey is approximately $18,500 to $23,500.