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ALTERNATIVES FOR IMPROVING URBAN TRANSPORTATION

— A MANAGEMENT OVERVIEW —

Prepared for
The Federal Highway Administration by
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FOREWORD

ALTERNATIVES FOR IMPROVING URBAN TRANSPORTATION – A MANAGEMENT OVERVIEW, was prepared as part of a course development program having the same title. The training course referred to throughout this publication is 3 days long has been conducted for a number of Federal, State, and local highways agencies. For information on the availability of the course contact your local FHWA Division Office.

This report is made available as a technology sharing report because it provides practical information that can be used to improve the efficiency of the existing transportation system. The emphasis is placed on "getting the most out of what we have." Alternatives presented include improving traffic operations, improving urban goods movements, ride sharing programs, demand management, Transportation pricing, and improved public transit.

A training kit is available to help professional instructors that may desire to give this course to transportation officials. The Kit includes visual aids, an instructors manual, and a student notebook. For further information on the training kit contact the Federal Highway Administration, National Highway Institute, HHI-2, Washington D.C. 20590

PREFACE

Mobility, frequently acclaimed as our fifth freedom, is the very fiber of our democratic society. It is the backbone of industry, and the principal sustenance of the urban community. Without mobility, progress in our community is stifled; with it, growth and prosperity prevail.

Mobility manifests itself in transportation. Transportation is not automobiles, buses, trains, airplanes, and other transport objects, but people and goods. The desires of people and their need for goods create the demand for transportation. Their preferences in terms of time, money, comfort, and convenience dictate the types or modes of transportation to be used. Transportation is not without its limitations: time, space and economy. Therefore, the basic premise of transportation management is to serve the people's needs within the constraints of time, space, and available resources.

Due to unprecedented advancements in technology and affluence of society in recent years, our current transportation system has developed rapidly to a stage of early maturity. That is, a basic system framework is established; we have extensive air, rail, highway, waterway, and pipeline subsystems throughout the country.

With such rapid development there are inherent inefficiencies in the system. These inefficiencies have resulted in operational problems, particularly in the urban areas, where demand is high and space is limited.

The time has come when we must concentrate on improving the efficiency of the existing system rather than expanding or replacing it. There are various alternatives available for the improvement of urban transportation, and this course is intended to provide for the transportation manager an overview of these alternatives, with emphasis on the applicability, the benefits, and the trade-offs associated with each alternative.

This course was prepared by the Texas Transportation Institute under contract number DOT-FH-11-8510 with the Federal Highway Administration, under the guidance of William L. Williams, Project Manager, and the UTOT Task Force, Jack T. Coe, Chairman. In the second phase of the contract, the course is being presented on a regional basis, one presentation in each region. Up to 15 additional course offerings may be scheduled at the option of FHWA.

Therefore, the contents of these course notes reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

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CHAPTER 1

INTRODUCTION TO COURSE

1.1 INTRODUCTION

Mobility, frequently acclaimed as our fifth freedom, is the very fiber of our democratic society. It is the backbone of industry, and the principal sustenance of the urban community. Without mobility, progress in our community is stifled; with it, growth and prosperity prevail.

Mobility manifests itself in transportation. Transportation is not automobiles, buses, trains, airplanes, and other transport objects, but people and goods. The desires of people and their need for goods create the demand for transportation. Their preferences in terms of time, money, comfort, and convenience dictate the types or modes of transportation to be used. Transportation is not without its limitations: time, space, and economy. Therefore, the basic premise of transportation management is to serve the people's needs within the constraints of time, space, and available resources.

In order that transportation management may be accomplished, it must be treated as a system with interactive capability. It is not sufficient to have independent systems attempting to satisfy the same objective, such as we have in operating private, public, and mass transportation as separate entities. They must be drawn together in a single system with management toward the common goal. This course is designed to bring together the concepts of managing the total transportation system, and to give an overview of factors relating to the transportation process.

1.2 THE URBAN TRANSPORTATION OPERATIONS TRAINING PROGRAM.

1.21 UTOT Program Objectives.

The objective of the UTOT Program is to provide a complete training program in urban traffic operations for management, supervisory, and technical personnel at the federal, state, and city levels.

1.22 UTOT Program Concept.

The program concept, as established originally by the FHWA Task Group on Urban Traffic Operations Training, and subsequently presented in the project prospectus, has not been changed appreciably. Principally,

the concept recognizes a common body of technology applicable to urban traffic operations with different interests and needs, dependent on the individual position of responsibility. Three general categories of responsibility are identified: Program Management, Project Supervision, and Technical Responsibilities. Thus, the three levels of responsibility set out for structuring the program are Management (Level 1), Supervisory (Level 2), and Technical (Level 3). The three levels are described as follows:

- *Level 1 - Management.* The course for this level should be developed as an overview of urban traffic operations, presenting the various elements or disciplines of traffic operations, their interrelationships, and their relationship to the total transportation system. The overview course should put resources, technology, and policy in proper perspective and facilitate rational consideration of the alternatives and consequences of decisions.

Material presented in the Level 1 course may include subjects covered in Levels 2 and 3, but the presentation and form will be abbreviated and oriented to management needs.

- *Level 2 - Supervisory.* This level of the program should consist of several courses in traffic operations for supervisory personnel who are responsible for instituting policies and decisions of the management. The courses at this level should present the latest technology, practices, and policies for the achievement of improved traffic operations. The principal objective of this level of the program is to upgrade the technological level of supervisory personnel to provide maximum implementation of the latest practices and technology.

- *Level 3 - Technical.* Courses at this level should be aimed at the professional and subprofessional levels of traffic operations where design and operational practices are carried out. The principal objective of this level is to upgrade the technical proficiency of operating personnel in the latest technological advancements in the field of traffic operations. Also, basic short courses on fundamentals of traffic operations will be included for the upgrading of personnel as basic assignments change within the operating agency.

1.23 UTOT Program Participation.

Level 1 - Management. The course at this level is designed for FHWA Division and District Engineers, FHWA Regional Staff, State Design and Operations Engineers, Urban Transportation and Design Managers.

Level 2 - Supervisory. Courses at this level are to be designed for engineers who have specific program responsibilities and have need for training in the managerial/technical aspects of a given discipline.

Level 3 - Technical. Courses at this level are to be designed for engineers/technicians/professionals working in a given project area and who need technical training in that area.

1.24 Recommended Courses.

General title descriptions of courses or course subject areas recommended for each of the levels are given below.

Level 1 - Management. One course, "Alternatives for Improving Urban Traffic Operations" provides an overview of alternative methods of solving urban transportation problems.

Level 2 - Supervisory. Nine courses are proposed, as follows:

Course 2.1 Traffic Engineering Fundamentals

Course 2.2 Management of Traffic Control Systems

Course 2.3 Capacity of Transportation Facilities

Course 2.4 Design of Urban Streets

Course 2.5 Lighting

Course 2.6 Management of Low Capital Improvement Programs

Course 2.7 Public Transportation - An Element of the Urban Transportation System

Course 2.8 Pedestrian and Bicycle Considerations in Urban Traffic Operations

Course 2.9 Safety Design and Operational Practices for Streets and Highways

Level 3 - Technical. An undetermined number of courses are recommended, to include the subjects listed below. It is anticipated that some of these courses are already in existence, some should be prepared by FHWA, and some should be prepared by universities and other institutions.

Traffic Operations

Signalization
Traffic Fundamentals
Freeway Control
Driver Communications
Urban Street Operations

Traffic Planning

Environmental Effects of Traffic Operations
Land Use
Site Development
Access Control

Design of Traffic Facilities

Capacity
Geometrics
Drainage
Lighting
Transit
Safety

Transit and High-Occupancy Vehicle Systems

Rail Systems
Bus Systems
Multi-Mode Systems

Data Systems

Computer Technology
Inventory Methods
Data Handling

1.3 MANAGEMENT OVERVIEW COURSE OBJECTIVES

The objectives of this course, the Level 1 Management Overview Course, are enumerated as follows:

- To identify the urban transportation problems of today.
- To explore alternatives for improving urban transportation.
- To identify the essential considerations for management decisions relating to alternatives for urban transportation.

This course is intended to provide the transportation manager with a broad overview of urban transportation alternatives, and to assist him in dealing more effectively with current transportation problems of the urban area. The significance of moving people and goods rather than vehicles is stressed. The primary theme is to "make the best use of what we have" through the implementation of short-range improvement alternatives such as the implementation of public transit, ride sharing, variable work hours, improved traffic operations, and others.

1.4 HISTORICAL DEVELOPMENT OF URBAN TRANSPORTATION - A Discourse on Where We Have Been and Where We are Going*

Transportation is everyone's concern - our entire society is geared to the mobility of people and goods. We all enjoy the privileges afforded by transportation, and we all suffer from its deficiencies. The average citizen drives his personal car to and from work, and enjoys the freedom and flexibility of choosing his own schedule for travel. For this privilege, he must contend with the problems of peak hour traffic. In most cities, this peak hour traffic presents a rather frustrating situation--noisy, crowded streets and freeways, and frequently stop-and-go conditions. In a word--congestion. As we in the transportation field view this daily ritual, we, too, become frustrated, because we know there is a better way, at least from our point of view. We see around us a street system choked with automobiles, and most of these automobiles, each carrying one person, have a capacity of 4 or 5 people; we note the 20-25% efficiency in space and energy utilization, and the seemingly needless contribution to pollution of the atmosphere. We are confident that our major transportation problems could be solved if the traveling public would exercise several of the more efficient transportation alternatives.

One alternative is to utilize the vehicle more nearly to its practical capacity. Increasing the average occupancy to three would reduce vehicular demand on traffic facilities by more than 50%. Also, if more people would ride the higher capacity transit vehicles, the peak hour congestion would be reduced. Further, we could stagger our work hours so that travel demand is spread more uniformly over longer time periods. Any of these alternatives would result in improved operation; so why have they not been fully implemented? Why are things the way they are?

Throughout recorded history, mankind has strived for freedom, independence and mobility. In this, the 20th century, all have been achieved. The first two - freedom and independence - are guaranteed through the democracy in which we live. Mobility - in fact a fantastic level of mobility - is provided through modern technology and the current state of personal affluence. And what is the result of this virtual state of Utopia? - Most individuals can travel when, where and with whomever they wish?

To better understand our current situation, let's review some history of urban travel. For centuries urban residents traveled within the city by walking. Transportation was not a major problem because cities were small, and all points within the city were accessible on foot within a reasonable period of time. Only the rich enjoyed the luxury of riding.

With the Industrial Revolution of the 1800's cities began to grow and expand in population,

* Narrative of an Audio-Visual Presentation

and with this growth came the need for traveling greater distances, which in turn increased the demand for improved means of transportation. Thus, animal-drawn vehicles became commonplace as a means of public and private transportation. The Industrial Revolution brought about new dimensions in transportation, and a new form of traffic congestion.

In the days of animal-drawn vehicles, most city streets were not paved. To provide a smoother riding surface and to permit one horse to do the work of several, many transit companies built street railways for horse-drawn transit vehicles. This horse-drawn tram was typical of those used in New York City in the mid 1800's. However, the advent of rails did not increase the speed or the range of horse-drawn vehicles.

Because he opposed the brutal whipping of horses, Andrew Hallidie sought a better power source for transit vehicles. Thus, he developed the cable car. Cable cars were not necessarily faster than the horse-drawn vehicles, but they eliminated the need for maintaining large herds of horses. Elimination of the horses also solved a very significant pollution problem! These two advantages brought about the installation of cable cars in several large cities around the nation, San Francisco being the first in 1873.

One cable car installation is illustrated here in Washington, D.C., about 1900.

Cable cars were limited in speed and distance, and were soon replaced by electric streetcars. Electric streetcar systems appeared in nearly every large city in America, and even in some cities of less than 5,000 population.

There is no doubt that the streetcar was a very significant development in urban transportation because it provided a longer range and higher operating speeds. Even so, streetcars did not eliminate congestion.

With the advent of the street car, many cities soon discovered that some streets were too narrow to accommodate streetcar lines and still serve wagon and buggy traffic, so they built transit facilities above the street. This facility, the 9th Avenue Elevated in New York City, was opened about 1875. The vehicles were initially steam-powered, but later were converted to electric power. Some elevated facilities, such as the Chicago "L" are still in service today.

Since transit vehicles using elevated facilities were free of the normal traffic interferences at the ground level, they could travel faster; thus, rail rapid transit was born before the turn of the century. Some cities objected to the poor aesthetics of the elevated facilities, and chose to build similar facilities underground; thus, the subway was born. Boston began its subway system about 1885, and New York City

opened the first segment of its system in 1904. Still, congestion was not eliminated.

The motorbus increased in popularity as advancements in technology improved operational capability. This steam-powered double-deck bus was used in London in the early 1900's. Passengers could ride on top, exposed to the elements, for about half-fare. It is significant to note that motorbuses became popular in London a full 20 years before they did in the United States.

About 1920, transit companies began replacing streetcar lines with bus lines because of the inherent flexibility of the bus as a transit vehicle. Buses were more compatible with other traffic, and routes could be altered as demand changed. Even so, buses did not eliminate congestion.

Today about three-fourths of transit ridership is carried by buses. The buses of today are usually air-conditioned and operate at reasonably good travel speeds, dependent upon traffic conditions, number of stops, and preferential treatment.

At this point, we have observed the evolution of urban transit forms from animal-drawn vehicles to gasoline-powered motor buses; but the major impact on urban transportation began in 1893 when the Duryea Brothers built the first gasoline-powered automobile. Little did they realize that they were unleashing a power that would totally revolutionize the transportation and lifestyles of the whole world. Originally a rich man's novelty, the automobile quickly became a device of utility because it satisfied man's inborn desire for mobility. Rapidly advancing technology, including assembly line production methods, soon provided a dependable automobile and one that was priced within the financial capabilities of most Americans. We soon became a nation on wheels, and mobility became our way of life.

Since the 1920's, automobile travel has experienced phenomenal growth, and we have tried valiantly to keep ahead of this growth with the development of new road systems. The first major road development was the Primary System, created as a part of the Federal Aid Highway Act of 1921. The Primary System was only 7 percent of the nation's rural mileage, so it was soon necessary to supplement it with other systems. As a result, the Federal Aid Secondary System was established in 1944. Also, in 1944 the Federal Aid Urban Extension system was created to provide continuity of the Federal Aid Primary and Secondary Systems through the urban areas. These three systems are commonly known as the ABC systems.

In 1956, the greatest of all peacetime public work efforts, the Interstate Highway System was begun. And the latest system, the Urban System was established by the Federal Aid Highway Act of 1973.

These systems are evidence that we have attempted to satisfy the ever-increasing demand for travel by developing new systems and building more facilities. However, the demands have increased more rapidly than we have been able to develop and to build new facilities.

Many feel that it is time to draw the line--to require some sacrifices to make the system more efficient. Alternative travel modes have been proposed as possible substitutes for the private automobile. We can recall several that were tried, only to be replaced by transportation modes more compatible with our preferred lifestyle. A return to rail rapid transit often is suggested as a solution to urban transportation problems. But, rail rapid-transit often requires a capital outlay greater than any freeway system, and in all but a few instances, it is difficult to justify the economic investment in view of a decline in transit ridership. A review of the causes of this decline would be worthwhile.

It is the general impression that the decline in transit ridership has occurred only since World War II. That is because data generally are plotted only for that time period.

To get the true picture of the decline, we should plot ridership data back to about 1900. Then we note that the decline actually began in the 1920's. Parenthetically, this corresponds with expanded usage of the automobile. We may note that transit ridership stabilized to some extent during the Depression of the 30's, and then peaked again during the war years when there was a serious shortage of automobiles and fuel.

Obviously, the major decline has occurred since World War II. Some have claimed that fare increases caused the decline, and proposed lower fares or no-fare transit service. It is true that the decline since World War II generally corresponds to fare increases, but this is more coincidence than cause and effect. It is important to remember that the decline in ridership began in the 1920's and was interrupted only by the unfortunate circumstances of a drastic economic depression followed by a major war.

Then what were the causes of a declining transit ridership? Certainly, the increasing availability of automobiles for private use has been a major factor. As shown in this illustration, the number of automobiles has increased proportionately with population since 1920. Even though the two curves are

parallel, the ratio of persons per automobile has changed drastically - 20 to 1 in 1920 as compared to 2 to 1 in 1970. Increasing personal income, or personal affluence, is probably the primary reason why Americans have been able to afford private transportation.

Another major factor in the cause of declining transit ridership is the type of housing made possible by the various transportation modes. Urban residents always have preferred the comparatively isolated domain afforded by the modern-day single family residence. Such a lifestyle could not be achieved because of the limitations imposed by early transportation modes. In this illustration, we see the historical growth of cities plotted on the background of the eras of various types of transportation. Note that during the era of horse-drawn and cable car transportation, major cities began to mushroom in population. In order to utilize the existing transportation systems, these additional residents had to crowd into about the same land area that the cities had occupied prior to their rapid increase in growth--that is, the land area which could be served by horse-drawn and cable-car transportation. The net result was high-density residential areas.

The electric streetcar provided higher operating speeds and greater ranges, so it allowed the cities to expand outward. Row-houses, such as these in San Francisco, were typical of residences built along new streetcar lines. The electric streetcar was readily accepted, not only because of its better transportation service, but also because it permitted a more desired form of housing.

When the motorbus and the automobile came along, they had the flexibility to expand into the open space between these corridors and to go even farther out. People readily accepted them because of the opportunity to achieve single-family dwelling units in and around large cities. The current lifestyle has in fact created a greater dependence on the automobile and lessened the accommodation of mass transit.

Thus, it appears that the major factors contributing to the decline of transit usage are:

- (1) Public affluence,
- (2) Increasing availability of automobiles, and
- (3) A desire for low-density housing.

These factors have combined to create a lifestyle in which transit may never return to its former role as the primary means of urban travel. Yet, there does appear to be an increasing need for some form of public transportation. We have seen that rail rapid transit is not new; it was actually developed before the turn of the century. But there has been a renewed interest in rail rapid transit. Its success in the modern-day setting depends on the success of new systems such as those in

Toronto, Montreal, San Francisco, Washington, D.C., and Atlanta.

Toronto was the first of these systems, opening its subway in the 1950's with modern stations and comfortable vehicles. The ridership was large initially and is still growing. Montreal opened a modern fixed guideway rapid-transit system just prior to Expo'67. Both systems are considered successful.

Before we conclude that the experience of these two Canadian cities is evidence that rail rapid transit would be successful everywhere, we should note some of the differences in lifestyles. Residents of both Toronto and Montreal live at much higher densities than those in many cities of the United States. Toronto has numerous high-rise apartment buildings while most Montreal residents live in row-houses containing six or more families each. Both Canadian cities have a history of high transit usage. Even though the subway stations are spaced about a half-mile apart to be in easy walking distance, surveys show that about three out of every four subway passengers ride to or from the subway station on street-cars or buses. Probably as many buses come to this one subway station in Montreal each day as come into many of our downtown areas. Even though their total transit ridership is increasing, they are encountering financial difficulties, and subway ridership seems to be declining.

The most recent fully operational system to open in the United States is BART, the Bay Area Rapid Transit System, serving the San Francisco-Oakland area. It is, indeed, more modern in appearance than any previous system, and was designed to be more automated. A trainman starts and stops the train; otherwise, it is computer controlled.

The vehicles are spacious, comfortable, and modern in appearance with upholstered seats and carpeted floors. In an effort to attract as many automobile drivers as possible, the BART system installed park-and-ride lots at each of its outlying stations. BART is indeed a beautiful system. It cost 1.7 billion dollars, or about 21 million dollars per mile! Others systems being built in the United States today include the Metro System in Washington, D.C., the cost of which is now estimated at 5 billion dollars, or about 50 million dollars per mile. The Atlanta system, now under construction, is expected to cost less because much of the system will be at-grade on existing right-of-way.

It should be recognized that transit systems in existing urban settings are not likely to pay their way through the fare box. Thus, it appears that the implementation of transit relates to the goals and objectives of the community more than purely economic considerations. In making decisions relating to urban transportation, the decision-makers must realize that rail systems have high initial

costs, require an extended time period for implementation, are fairly inflexible, and require high-density development to be cost-effective. For these reasons, many cities are considering other ways of providing mass transportation into the center of the city.

Bus rapid transit provides an expedient means of mass transportation. Such a system can be implemented in a much shorter time at a lower capital investment because it can utilize the existing highway network. The quality of bus rapid transit as compared to rail rapid transit is largely a function of the line-haul trip. To make the systems comparable, steps must be taken to reduce the effects of prevailing congestion on bus travel. This is being done in several projects around the country. An exclusive busway is provided in the median of the Shirley Highway leading into Washington, D.C. In Minneapolis, Interstate Highway 35W is being managed to provide priority treatment at the ramps, but otherwise buses operate in mixed flow with other traffic.

In other cities, freeway lanes are reserved for the exclusive use of buses and other high-occupancy vehicles. In still other instances, contra-flow freeway lanes enable buses to take advantage of unused capacity in the off-peak direction.

On the Oakland Bay Bridge, buses and other high-occupancy vehicles are assigned exclusive lanes to by-pass the toll plaza congestion.

At ramps onto freeways, buses are given priority treatment to reduce delay. Buses by-pass the waiting queue of passenger cars by way of a turn-out or a separate ramp.

Cities are also implementing procedures to speed up the operation of buses in the downtown area, such as reserving lanes exclusively for buses during the peak hour. This allows the buses to keep moving rather than being stopped in traffic jams. Others are designa-

ting some streets as "bus streets," exclusively for the operation of buses.

Where Do We Go From Here? Although this appears to be a question for the crystal ball, there are a few facts that may shed some light on the subject.

First, our desire for personal mobility will not be denied as long as we have the affluence to support it. Even in the face of fossil fuel limitations and the environmental concerns, individual mobility will prevail.

We have a tremendous investment in our system of streets and highways, and we will continue to develop and to use this system for personal transportation. No doubt, there will be changes in the way this system is used, and in the vehicles using it. For example, the personal vehicle is shrinking in size and weight, while the transit vehicle is being enlarged to carry more passengers.

There is obviously a maximum amount of the urban space that can be reserved for transportation. As the demand for this space gets greater, we will see efficient compromises take place. For example, most of our cities today experience congestion in the densely developed commercial areas and on the arterials leading into these areas. On the other end of the trip, there is virtually no congestion. Such a condition is conducive to mixed mode operations. The individual may use his private vehicle for travel to an intermediate terminal point and then complete the remainder of the trip by a transit mode.

The solutions to urban transportation problems are not simple. They cannot be simply legislated, regulated or purchased. Solutions are achieved by first identifying the problems, setting objective solutions acceptable to society and applying all available resources to the achievement of these objectives.

CHAPTER 2

ALTERNATIVES FOR TRANSPORTATION IMPROVEMENTS

SESSION OBJECTIVES:

1. *To identify the basic concepts of urban transportation improvements--reduce demand or increase capacity.*
2. *To expand each of the basic concepts, introducing alternatives of transportation improvements.*
3. *To summarize transportation improvement alternatives for an overview, and to lay the groundwork for the remainder of the course.*

2.1 INTRODUCTION

If we accept the general goal of the urban transportation system as the "movement of people, goods and services in a safe and efficient manner within the constraints of the community's social, economic and environmental goals", then there are several alternatives available to us for the achievement of this goal. The purpose of this session is to review these alternatives briefly and attempt to achieve a total perspective. Then, we will pursue each of the alternatives in more detail, from a management viewpoint, in subsequent sessions.

The various alternatives for transportation improvements can be categorized under two basic concepts--reduce demand or increase capacity.

2.11 Reduce Demand. The alternatives for reducing demand are expanded considerably if we assume that this may be accomplished by:

- Reducing the number of person trips, i.e., reducing the necessity for people to travel.
- Reducing the number of vehicle trips, i.e., increasing the number of persons per vehicle.
- Dispersion of peak period demands, i.e., changing or spreading the time frame by which people travel.

2.12 Increase Capacity. Likewise, alternatives for increasing capacity are more numerous if consideration is given to:

- Providing additional facilities.
- Expanding existing facilities.
- Improving the efficiency of existing facilities.

2.2 CLASSIFICATION OF SOLUTIONS

Improvements to urban transportation systems at this point in time must be extremely "time-effective" and to a great degree, "money-effective." That is, improvements must have a "quick pay-off" and be within the current financial constraints. Therefore, it is necessary that we consider the classification of improvements based on high-capital, low-capital or non-capital expenditures.

2.21 High-Capital. This classification relates to the acquisition of right-of-way, construction of new facilities and the purchase of rolling stock. It applies equally to the construction of new highways and rail-rapid transit systems. Characteristics of alternatives falling within this class are similar.

- Require long lead times. Several years are required for the planning/design/construction process. Any freeway, BART, Washington Metro and other projects now being built are evidence of lead times required.

- New construction costs are high. Urban freeways now cost over \$1 million/lane-mile, and the new underground rail-rapid transit systems are costing \$25-45 million/mile.

- Perpetuation of current transportation inefficiencies. Particularly in terms of urban freeways, additional facilities will permit the continuation of the private auto, one vehicle-one occupant trend.

- Perpetuation of auto-oriented land use form. As long as we continue to satisfy the unbridled individual demand, land use will continue to develop according to the current trend.

Alternatives falling in the High-Capital classification are not a consideration in this course.

2.22 Low-Capital. This classification relates primarily to minor revisions of the physical facility or system for the improvement of operational characteristics. Alternatives within this classification are called "intensive" improvements because they build upon an initial capital outlay, and generally provide greater effectiveness for dollars invested. They take three basic forms:

- Improvements in capacity. Capacity relates to the design of the facility. Alter-

natives included are intersection improvements, mid-block improvements and, in general, the elimination of bottlenecks, provision of larger transit vehicles, shorter headways, etc.

- Improvements in Operations. Operations relate to control or operational strategy. Thus, this class of low-capital improvements would include signal system improvements, one-way streets, provision of reversible flow, etc.

- Modal Preference. This group of alternatives relate to changes in travel mode in an effort to improve overall transportation services. Included are purchase of buses, construction of exclusive bus ramps, car pool accommodations, bike lanes, etc.

2.23 Non-Capital. This classification relates primarily to regulation and management rather than physical changes in operational facilities. Non-capital improvements perhaps require the least lead time because they deal with policies and methodologies. Example: Non-capital improvements are transportation pricing, restriction of vehicles, changes in bus routes and schedules, land use restrictions, etc. However, these alternatives can probably have the greatest effect on society and life style.

2.3 REVIEW OF DEMAND-ORIENTED ALTERNATIVES

These alternatives are based on actions that will reduce the demand for transportation. These generally are time-related in that they are aimed primarily at reducing demand during the peak travel period.

2.31 Transportation Pricing. Transportation pricing to regulate demand is a concept based on the premise that transportation demand is inversely proportional to the price of transportation. This may or may not be true, dependent on the flexibility of personal income. As we have seen in the increased fuel and automobile costs, people are apparently adjusting their spending priorities rather than altering their travel patterns. There is a great need for additional information regarding the transportation pricing aspects of regulating travel. Presently, there appear to be two basic pricing alternatives.

2.31.1 Dis-incentive Pricing. This term is used to describe the monetary process of discouraging travel by private auto by increasing travel costs. This may be accomplished by levying taxes or tariffs on fuel, automobiles, tolls and other methods, all for the purpose of increasing the cost of travel beyond the individual's capability or willingness to pay. Some dis-incentive pricing schemes may be termed arbitrary while others are termed rational. Arbitrary pricing

relates to pricing for control purposes, not for recovery of costs. The consequences of arbitrary pricing are mostly negative. First, arbitrary pricing is discriminatory against lower income groups. Further, there is widespread objection to taxation, in general, and especially when taxes are levied for control purposes rather than to support a societal benefit.

- Dis-incentive pricing may be termed rational if transportation is priced according to its actual cost, including hidden transportation costs. Some have proposed pricing peak hour transportation in accordance with facility, environmental, and other societal costs such as time and additional energy consumption during congestion. Such a pricing policy has a logical basis and should not be too objectionable to the public. However, administrative methods are not well defined, and it appears that it would be a very difficult task. One approach would be to charge tolls on freeways during the peak hour. However, the collection of tolls would create additional congestion and increase operating costs.

2.31.2 Incentive Pricing. This term is used to describe pricing as a means of encouraging the use of more efficient transportation modes, through a reduction in travel costs. Several incentive pricing schemes are currently in use. These include reduced tolls for buses and carpools, reduced parking fees for car pools, reduced peak hour bus fares, company-furnished vans for vanpools, and others.

2.32 Peak Period Dispersion. This is a concept based on managing travel demand relative to time through the regulation of work schedules. Alternatives include shorter work week (three or four work days) and variable work hours. The latter appears to provide the greatest potential benefit without greatly disrupting life styles. Some elements of the business industry are already utilizing the 4-day work week, and it has been predicted that 35 to 40% of the work force will be on a shorter work week by 1990. By instituting 10-hour days, the work trips are moved off the normal peaks. There is a potential for reduced travel, but it appears likely that extended weekends may result, instead, in increased travel.

Variable work hours, including staggering of fixed work schedules and flexible work hours which permit the individual to select starting times, seem to be more adaptable to current life styles, and probably do more to relieve peak period congestion. A major project by the New York Port Authority has demonstrated the effects of staggered work hours. More recently, Canadian government employees in Ottawa initiated an extensive variable work hours project. Both of these

will be discussed in more detail later.

2.33 Ride Sharing. This concept relates to alternatives for increasing vehicle occupancy by providing time and money-saving incentives. Specifically, reference is made to the encouragement of car pools and van pools. Incentives provided have included the use of priority vehicle bus lanes, reduced tolls, reduced parking rates, preferential parking locations, and others. Some companies have instituted incentive plans whereby the company furnishes van-type vehicles for groups willing to participate in group riding.

2.34 Improving Public Transportation. This is an approach to increasing public transportation ridership through service incentives. Incentives include improved scheduling and routing of local bus systems, the establishment of Bus Rapid Transit services, demand-responsive systems (Dial-a-Ride, etc.) and others. There is a need to consider revision of regulations relating to public transportation, as well as considering the need for subsidies. There is considerable potential for the improvement of public transportation, especially when it is brought under the control of the urban transportation management.

2.35 Facilitating Bicycle Travel. This is an approach to encourage people to use bicycles rather than automobiles through service and convenience incentives. In concept, this appears to be a viable alternative; however, the manager should consider the climatological influences, the realistic reductions in demand possible, and the costs of providing bike facilities. Bicycle facilities take two basic forms:

- Bikeways--separate paths constructed for the exclusive use of bicycles.
- Bikelanes--a part of the street designated and marked for the exclusive use of bicycles.

The accommodation of bicycle travel creates two significant problems that must be considered: the storage and security of bicycles at intermodal terminals, and the security of bike riders on bikeways through secluded areas such as parks.

2.4 REVIEW OF CAPACITY-ORIENTED ALTERNATIVES

Capacity-oriented alternatives for improving urban transportation relate primarily to methods of increasing vehicular capacity of traffic facilities. Not to be overlooked, however, is the added efficiency that may be realized by coupling these improvements with demand-oriented alternatives to produce

an end result of more efficient people movement. Alternatives to be discussed in the capacity-oriented category include: building new facilities, improving traffic operations, improving pedestrian facilities, and improving urban goods movement.

2.41 Building New Facilities. Building new transportation facilities is certainly not one of the quick pay-off methods of solving today's urban transportation problems. Certainly, there is a continuing need for a balanced expansion and up-grading program of building new transportation facilities, but such a program can no longer be substituted for improving the efficiency or people moving effectiveness of existing systems. To achieve maximum effectiveness a balanced program of immediate and long-range projects within the realm of urban transportation system management must be implemented.

2.42 Improving Traffic Operations. This approach relates to improving flow on existing street systems through traffic engineering and relatively minor design improvements.

2.42.1 Traffic Engineering Improvements. Alternatives related to improving traffic operations through control, regulation or alteration of major flow patterns include the following:

- Removal of Parking--full utilization of the street for vehicular flow purposes.
- One-way Systems--changing major flows to increase the utilization of street space, improve signal progression, and reduce the capacity-reducing conflicts.
- Reversible Flow--regulating street use by direction to better apportion available street space to demand by directional peaks.
- Traffic Control Improvements--Improving control methods and strategies for more efficient handling of traffic.

2.42.2 Design Improvements. There are several alternatives related to improving the physical features of the street to more efficiently accommodate traffic. These include:

- Intersection Improvements--provision of separate turn lanes and better alignment of approach lanes so that more uniform traffic flow may be achieved.
- Mid-Block Improvements--proper design for access control and mid-block turns to improve the safety and efficiency of the street.

2.42.3 Freeway Operations Management. Most freeways in major metropolitan areas become overloaded during peak periods, and their traffic handling capability is reduced due to congested conditions. Their operational efficiency is greatly improved by regulating access to the facility so that traffic flows smoothly at volumes very near capacity of the facility.

Although freeway operations management is a specialized complex element of urban traffic operations, it can be categorized into two basic activities.

- Recurring Incident Management. A recurring incident is one which is time predictive; generally, recurring incidents consist of bottleneck situations or simply demand exceeding capacity. The basic operational strategy is the metering or closure of entrance ramps to regulate the demand and thus improve operation on the freeway.
- Non-recurring Incident Management. The non-recurring incident is any random capacity limiting event that is not time predictive, such as a stalled vehicle, an accident or other similar situations. The operational strategy involves detecting the incident, identifying the cause and executing corrective measures to restore the capacity.

In some instances freeway operations management has been expanded to include systems considerations in the operation of an entire freeway corridor. The objective in corridor operation is to optimize the traffic flow on the entire corridor street network. Integrated with this is the implementation of priority treatment of high-occupancy vehicles.

- Special Bus Lanes. Bus travel times are improved by reserving exclusive lanes (and some time entire streets) for bus movement where congestion would otherwise prevail. These may be in the downtown area or they may be on freeways, where they also may be used by other high-occupancy vehicles such as carpools and vanpools.
- Contra-Flow Bus Lanes. In downtown areas, contra-flow bus lanes are normally employed to assure exclusive use by buses. On freeways, contra-flow lanes are generally provided to take advantage of available capacity in the non-peak direction of travel.

2.42.4 Using Larger Public Transportation Vehicles. There is a larger generation buses designed to increase the people-moving capability of street vehicles. These can be described as two basic types:

- Large Single Units. The new AASHTO publication, A Policy on Design of Urban Highways and Arterial Streets, 1973, provides design criteria for the consideration of

the large bus as a critical design vehicle.

- Articulated Bus. Now being tried on an experimental basis, the articulated bus is a large capacity vehicle that "bends in the middle" so that it may negotiate turns designed for normal sized vehicles.

2.43 Priority Treatment of High-Occupancy Vehicles. When capacity considerations are made on the basis of people capacity rather than vehicle capacity, it becomes practical to give special consideration to vehicles that offer a potential for increasing the people capacity of streets. This requires new thinking, for heretofore, such vehicles have contributed to capacity reduction when capacity is equated in numbers of vehicles. Priority methods that have been employed are:

- Signal Pre-emption. Buses are equipped with electronic control gear through which the driver of the bus can "call for" a green signal and thus avoid stops and delays. FHWA is now in the process of developing a "passive" pre-emption system.
- Reserved Loading/Unloading/By-Pass Lanes. The objective is to provide facilities which reduce the time required for buses to load, unload, and move through bottleneck points such as intersections and freeway ramps.

2.44 Improving Pedestrian Facilities. One of the major factors in safety and operational efficiency of urban arterials is the vehicle/pedestrian conflict. Improving these conditions will improve vehicle capacity and enhance the incentive to walk more frequently. Some alternatives for the reduction of pedestrian conflicts are:

- Improvements to pedestrian facilities in the CBD
- Integration of special pedestrian facilities in high density areas
- Making provisions for pedestrians in planning, design and operational practices in the urban area
- Providing pedestrian grade separations

2.45 Improving Urban Goods Movement. In the CBD area, one of the major capacity restraints is the partial blockage of traffic and pedestrian movements by the activity of loading and unloading of goods, and the provision of services from a curbside "loading zone." Obviously the movement of goods is vital to the business community, but the effect of this activity on the overall transportation system may be minimized by proper management. Some of the improvement alter-

natives are:

- Providing more off-street loading facilities
- Scheduling deliveries for off-peak periods
- Enforce loading zone use regulations
- Consolidate receiving in major buildings
- Selective routing and loading zone provisions

2.5 SUMMARY

At this point, it is evident that there are many alternatives for the improvement of urban transportation. The success of these alternatives is dependent upon the specific needs and the community goals established by the urban area in question. Above all, the successful implementation of these alternatives will depend to a great degree on the management of transportation within the urban area.

CHAPTER 3

THE URBAN TRANSPORTATION PROBLEM

SESSION OBJECTIVES:

1. *To introduce the concept that the principal indicator of urban transportation problems is congestion.*
2. *To expand this concept to secondary indicators that relate to energy consumption, environmental effects, and transportation costs.*
3. *To explore some illustrative factors relating to urban transportation problems for orientation to the course material.*

3.1 INTRODUCTION

The principal indicator of the urban transportation problem is congestion. Congestion occurs during peak periods, and results from the demand for specific forms of transportation exceeding the capacity of transportation facilities relative to time. Secondary indicators less obvious to the users are:

- Excessive Energy Consumption
- Environmental Pollution
- Hidden Transportation Costs

If congestion and its related effects constitute the urban transportation problem, then it seems worthwhile to explore and discuss the various factors that contribute to congestion. Seven major factors are included. If these seven factors are actually significant, they have alternative solutions, but not necessarily achievable or cost-effective solutions. We may not have all the answers, but recognition of the problem is a good start toward a solution. We will review these factors and discuss the various causes and corrective measures. This should give us a good start on material to be presented in this course.

3.2 SUBJECTS FOR DISCUSSION

3.21 Coincidence of Work Trips. Even though our nation is the leader of the democratic process, founded on individual freedom, we are perhaps the most regimented nation with respect to our work habits. Our business world is organized on a fairly rigid schedule, generally 8 to 5. The degree of regimentation produces the time-oriented transportation demand that in turn causes peak period problems. Such congestion problems are not unique to the auto system, but

affect all modes: rail, bus, elevators, sidewalks, etc. Problems caused by the coincidence of work trips overshadow the sufficiency of our systems for the remaining 21 or 22 hours of the day. There are several alternatives to the amelioration of the situation, but which are most applicable?

- *Will the construction of additional transportation facilities solve the problem?*

In theory, building to satisfy demand is a solution that can be achieved, provided the resources are available. This has been the philosophy of transportation management for a number of years, because transportation facilities, in general, were inadequate! A good highway system was necessary to provide mobility, particularly in low density areas. Rail systems have been developed to provide mobility in densely developed areas. To expand these systems further at this time would serve the purpose of accommodating demand rather than providing basic mobility. Because our resources are limited, policy at this time should be to use the existing systems more efficiently rather than satisfy an expanding personal demand.

- *Is the changing of work schedules a viable solution?*

The changing of work hours, either staggering hours or shortening the work week is an obvious solution from the operations viewpoint. Complementary questions are, "What will be the effect on industry?", and "What are the possibilities of implementation?" At this point, all questions appear to have positive answers. Much is being done on an experimental basis and the next few years will be productive years in this area.

- *How much spread is needed to relieve congestion?*

This depends on operational measures. For example, how much does peak period demand exceed capacity? The extent of participation in altered work schedules depends on the particular urban area and will change as the urban area grows.

3.22 Separation of Employment and Residence. This is one of the "values" of our society that is deeply ingrained. It will change only as personal preferences change; and personal preferences are regulated primarily by our affluence or ability to pay, and our consideration of personal alternatives and consequences.

- *Why do people prefer not to live and work in the same neighborhood?*

The principal reason is environmental considerations. Work activities are not compatible with the quiet, private living environment preferred by most.

- *What changes must be brought about to reduce work trips?*

To reduce work trips, the worker must be brought into closer proximity with his job, or reduce the number of work periods per week. In either case, these changes will require changes in social attitudes and life styles. There is some indication of these changes taking place, e.g., the large number of apartment complexes, but such changes are definitely long term.

3.23 Use and Occupancy of the Automobile.

- *Why is the automobile so popular?*

It provides the independence and mobility that is desired by practically everyone. The affluence of our society and the development of technology makes it possible for practically everyone to own a personal auto.

- *Why do people tend toward one vehicle - one occupant?*

Simply because it is the ultimate of independence and they can afford it. Further, our transportation agencies in government have assumed it a societal responsibility to satisfy demand. Even some of the transportation leaders have developed guilt complexes because of this seemingly liberal attitude, but we should exude pride rather than apology. We have built an excellent transportation system that can be used in many ways to satisfy the needs of society, but with full realization of the alternatives and consequences. Societal demands should be satisfied if society is willing to bear the consequences.

- *What are the alternatives?*

There are many--car pooling, public transit, bicycles, walking, and others to be developed in the future, no doubt.

3.24 Availability of Commuter Corridors.

Some claim that there are relatively few commuter corridors, and one alternative would be to develop new corridors.

- *What factors limit the availability and capacity of corridors?*

The urban street systems in most cities have been developed around the skeletal framework of the highway system leading into and through the city. Cities have tended to let

the state "spend the money" rather than finance arterials at the local level. Thus, commuter corridors are largely limited to the community highway system.

- *How can corridor availability be expanded?*

In many instances, additional commuter corridors may be provided by upgrading and providing continuity to existing secondary arterials. As funding programs are developed and manpower capabilities of the urban areas are expanded, new corridors may be created by improvements to existing streets.

3.25 Transportation Costs. Transportation costs are many, varied, and frequently intangible, or difficult to positively define.

- *Is the individual aware of the actual cost of private transportation?*

No, most individuals are not even aware of the out of pocket costs, and certainly are not aware of the hidden costs.

- *What are the individual costs?*

Individual costs can be categorized as:

Capital Outlay (Rolling Stock)
Operating Costs
Taxes, Insurance, Interest
Facility Costs
Environmental Costs

One thing not evident is the variation in transportation costs related to congested operation.

- *Can transportation pricing be used to manage vehicle use and occupancy?*

Present indicators suggest that it cannot. Recent increases in fuel costs have been absorbed in the family budget process. Transportation costs can be applied more equitably. For example, those who choose to drive in congested conditions perhaps should bear the additional costs associated with the operating conditions.

3.26 Availability of Public Transportation.

Some claim that individuals do not use public transportation because it is not available. An ironic situation--others say that it is not available because of a decline in ridership.

- *Is the availability of public transportation a key factor?*

Yes. To those who would use it. In general, public transportation is not available because of the seemingly unrealistic costs in providing public transportation in low density residential areas. We must devise methods of satisfying current residential

area needs on the one end with high-density area needs on the other end of the trip, and accomplishing this with a reasonable degree of compatability.

● *What factors relate to availability?*

Primarily routing, headways, scheduling, and trip speed. If these factors can be dealt with satisfactorily, public transportation will regain popularity.

3.27 Congestion Effects. Congestion is not unique to the current generation or to the current century. Congestion is a result of society. Throughout recorded history, people have tended to congregate, and to breed, or multiply. These, along with the desire for mobility, constitute congestion. Congestion may be a natural constraint of social behavior!

● *Can we achieve a balanced transportation system without the constraints of congestion?*

So far, we have not been able to. Congestion has been a prime motivation in improving transportation systems, but increased demands always seem to negate the improvements. Perhaps the realistic view is to manage congestion at the "tolerable threshold".

● *Can synthetic constraints be substituted for the natural constraints of congestion?*

Many have been suggested--only a few have been tried. Transportation pricing has been suggested, but most elected officials have not mustered the intestinal fortitude to try it. Legislation and regulation practices are reasonably successful--to the extent that they are exercised. For example, freeway ramp control is a regulatory type of synthetic constraint.

CHAPTER 4 FACTORS INFLUENCING URBAN TRANSPORTATION NEEDS

SESSION OBJECTIVES:

1. *To identify some of the social, economic, demographic and political influences on urban transportation systems.*
2. *To explore the relationships of land use patterns and the efficiency of urban transportation systems.*
3. *To explore the extent to which transportation is a constraining element on the location and size of concentrated activity centers.*

4.1 INTRODUCTION

Urban areas are dependent upon transportation for their development and continued existence. The nature and efficiency of the transportation system determine the magnitude and distribution of economic and demographic activity. Conversely, a wide variety of economic, social, and political factors interact to affect the type, nature, and configuration of urban transportation systems as well as the general urban form. The following are indicative of these factors:

- Total population -- The larger the population of the area, the greater the total number of trips that will be made; hence, the more extensive the transportation system required. Moreover, the large cities provide aggregations of people that are of sufficient size to present significant market groups. For example, if only 15 percent of the population of an urban area is willing to accept high density land use patterns and use mass transit, a city of two million population presents a significant and economical market. The market presented by a city of, for example 50,000 population is so small that a fixed way system is not justifiable.

In small towns, the scale of new development commonly is so small the city is concerned with the details of new local residential streets. In large growing metropolitan areas new development is on such a scale that the city should be primarily concerned with the alignment of major streets and general criteria for the design of collector and local streets.

- Population distribution -- At gross population densities of less than 2,500 persons per square mile, the automobile is a very economical and energy efficient mode of transportation. However, with densities greater than 10,000 to 25,000 persons per square mile, fixed way transit systems become economically and financially feasible if a significant amount of such development is organized in a defined corridor.

- Geography -- Major geographic features such as rivers and mountains, resulting in bridges, tunnels and mountain passes, frequently constitute major restrictions in the transportation system. In many cases, additional capacity through the bottleneck location cannot be achieved realistically through physical reconstruction; on the other hand, fixed way systems or preferential treatment to high occupancy flexible way systems may make maximum utilization of existing transportation facilities.

- Income levels -- Experience in the United States, as well as other countries, indicates that increased auto ownership and use are correlative with increased income. Transit ridership is observed to decrease as income levels increase.

- Governmental policy -- A governmental policy that encourages individual home ownership carries with it an implication of low density travel patterns and a reliance on the private automobile. A policy of fostering high capacity fixed way systems, such as rail rapid transit, should have a concurrent policy discouraging ownership of detached dwellings and encouraging extremely high density residential patterns.

Conflicting policies, such as encouraging ownership of individual detached housing units, while encouraging fixed way transit systems through low fare structures, will necessitate large subsidies and will encourage economically inefficient development patterns.

4.2 URBAN TRAVEL AND DEVELOPMENT PATTERNS

Population growth and continued urbanization have resulted in increased demand for numerous public services and urban facilities. In many urban areas, the level-of-service provided by some segments of the street system is no longer acceptable to the urban resident. The dissatisfaction over the congestion on the urban streets today apparently reflects increased expectation on the part of the public.

In actuality, the level-of-service (as measured by the distance one can travel in a given period of time) has improved. The San Diego (1) and Los Angeles (2) Driving Time Studies provide the most complete documentation of changes in automobile travel times. These studies document that peak period travel times are equal or slightly less than in the 1940's. Off-peak travel time has decreased substantially, even though the population has increased by several million.

If the total number of trips made in any urban area over a day's time were uniformly distributed over the 24-hour periods, the street system would not experience severe congestion. The congestion results from the attempted use of the available space at specific times, especially the a.m. and p.m. peak hours when the hourly demand generally accounts for 8 to 12 percent of the 24-hour traffic. Mass transit systems, unfortunately, experience even more severe peaking characteristics; peak hour demand in the direction of major flow is commonly 35 to 50, or more, percent of the 24-hour directional passenger traffic. Thus, the question, "Should peak period demand be accommodated?" is not easily avoided by proposals to replace the auto with some other type of passenger transport.

Increased capacity for the movement of persons and goods can result only from the more efficient use of time and/or provision of more movement space. Expansion of movement space can be accomplished by either the construction of additional facilities or by employing rolling stock that can move a larger volume over a given fixed way. In the long term, a balance between the transport system and land use patterns must be provided if an efficient urban form is to be achieved.

4.21 Land Use and Transportation Relationships. In many cases, the land use plan and transportation plans for a city are developed separately. Herein lies a great fallacy of judgment, for these two elements are, and must be, one in the same plan. A decision with respect to one imposes a limitation on the rational decisions that may be made with respect to the other. In effect, decisions in regard to transportation and land use must be made conditional on one another -- rather than being made independently. The degree of relationship between these conditional decisions determines the "balance" in the total urban development.

The term "balanced transportation" would be best used to denote a balance between land use type/intensity and transportation -- whatever the mode or modes. The application of two or more modes in any single urban area would more properly be defined as a "multi-modal transportation" system. A recognition of the interrelationships between land use and compatible forms of transportation is the key to effective urban development planning and the provision of transportation facilities.

4.22 Activity Patterns and Travel Demand. The distribution and density of urban activities dictate the resulting urban travel patterns. This, in turn, establishes the economic feasibility of the various modes of transportation for specific point-to-point movements.

In an economic sense, the different modes of urban transport are substitutes - not alternatives - for one another. For the urban resident, the concept of alternatives involves a mix of goods and services, including transportation, housing, neighborhood amenities, schools, etc.

Alternative urban forms involve choices between different comparable arrangements of residential, commercial and industrial development together with the appropriate interconnecting transportation. Such alternatives involve basic choices relative to residential type, number and size of commercial retail centers, employment distribution, etc.

Urban areas which have developed at low densities, typical of single family detached dwellings, also have dispersed travel patterns. Although an urban arterial street or freeway may have extremely large traffic volumes, only a few of the vehicles may be traveling between the same points. For example, the Gulf Freeway in Houston carries over 200,000 persons per day; only about 10 percent of these trips are going to or from the downtown area. Although these trips have a relatively common destination, they originate at a wide variety of locations within an area of some 40 square miles. The vast majority of the person trips are extremely diffused by location and time.

The preference for low density housing is clearly indicated by a study conducted for the Connecticut Interregional Program (3) in which the large majority of the respondents indicated that they prefer their present housing or housing of a lower density. A mere 4 percent of those residing in single family structures situated on small lots less than 60 feet wide indicated a preference for higher density housing. Of the residents in garden apartments, only 16 percent indicated that they prefer this type of housing; the remainder indicated preference for lower densities. This suggests that the recent boom in apartment housing is for reasons other than its preference as a housing type. This shift is most likely due to a combination of rapidly-escalating prices for single family structures and high interest rates, combined with the failure of disposable income to keep up with inflation.

A recent international survey by Gallup International Research found similar preferences between Americans and residents of other industrialized nations. Nearly one-half indicated a preference for living in a small city, town, or village; less than 20 percent indicated a preference for large cities (over 500,000 population). Of United States respondents living in cities over 500,000 population, only 27% indicated a preference for living in a city of this size. These preferences result in low density urban development that cannot be served economically by a fixed way rapid transit system. Conversely large high density urban development cannot be efficiently served by automobiles.

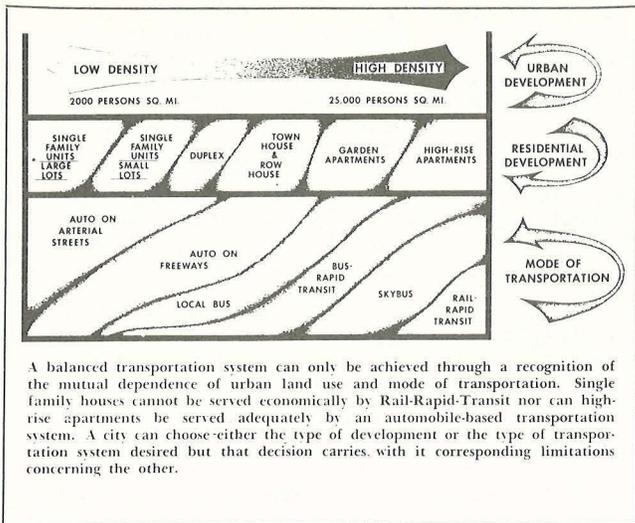


FIGURE 4.1 Balanced Transportation - Land Use

The interrelationship between various types of residential developments and compatible modes of transportation is portrayed schematically in Figure 4.1. The upper portion of the figure depicts the overall measure of the type of urban development, expressed in terms of gross population density. The center segment depicts the housing types that characterize residential development from low to high density, while the lower segment reflects the mode of transportation, or mixture of modes, that would be appropriate to serve an urban area of that type of development.

When the residential housing stock consists of single family dwelling units, the resulting relatively low average density is a city that can be best served by the automobile operating on a well-designed system of freeways and arterial streets. However, substantial development of garden apartments and high-rise apartments results in population densities which generate traffic patterns that cannot be served by the automobile alone. Under such conditions, some of the mass transit will be required.

This might be demonstrated by evaluating two drastically different modes of transportation and evaluating the urban forms that each would require. Automobiles on the one hand and rapid rail transit on the other constitute both ends of today's urban transportation technology spectrum. Cities could be designed to be served adequately by either mode of transportation, but they would require totally different urban forms and would result in significantly different lifestyles.

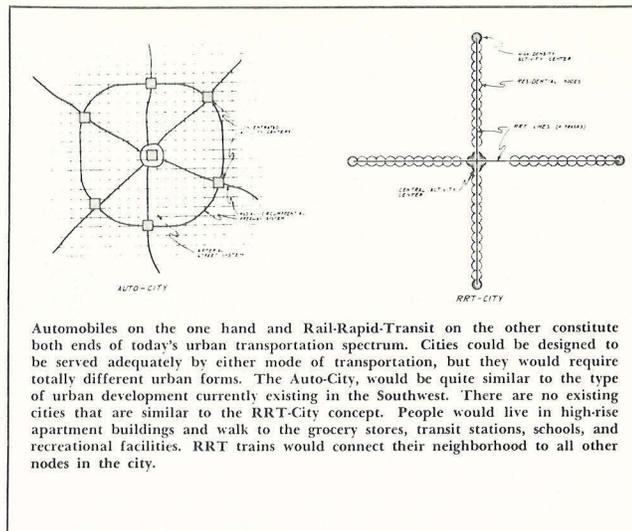


FIGURE 4.2 Comparison of Transportation Oriented Urban Forms

The resulting hypothetical urban forms for two such cities would be similar to those depicted in Figure 4.2. The auto-city would be quite similar to the type of urban development of cities that have largely developed since the automobile became widely used. There are no existing cities that are similar to the RRT-city concept.

The basic neighborhood unit in the auto-city is an area covering about one square mile, bounded by arterial streets, and containing about 1,000 single family dwellings on individual lots. The principal transportation facilities ideally consist of primary arterial streets at one-mile spacings combined with a radial-circumferential system of freeways. Such a street pattern stimulates a strong focal point in the center (downtown), but other areas of concentrated activities would develop at highly accessible locations. The auto-city might look very much like Houston or Los Angeles.

In the hypothetical RRT-City, people might live in residential nodes containing about 25,000 persons centered around a transit station. Each node would need to include about 100 high-rise apartment buildings (10 stories tall, housing 80 families each) together with elementary schools, a junior high school, two to four supermarkets, other shopping facilities, and some offices. Buildings would be clustered around the transit station so that very few walking trips would be more than one-half mile and generally 1/4 mile or less. Recreational activities and open spaces (parks, bicycle and foot paths, golf courses, ball parks, tennis courts, etc.) would surround each residential node.

The RRT corridors might form a cross, with the principal focal point (downtown) being at their intersection. Each of the four corridor legs extending outward from the center would need to include some ten residential nodes with the stations spaced about one mile or more apart. Each corridor would contain housing for 250,000 persons - enough to support high schools, a junior college, hospitals, a large regional shopping center, and considerable industrial activity.

If two such cities were properly designed, both would have pleasant environments; however, the urban forms and living conditions would be drastically different. In the auto-city, people would live in single family houses with individual yards. Residents of the RRT-city would live in high-rise apartment buildings; however, they probably could have such amenities as a swimming pool, landscaped commons, and other distinctive features.

One of the significant differences in the two cities is the type of mobility provided by the transportation systems. In the auto-city each family utilizes an automobile to make any trip it desires, urban or intercity, at any time. There would be no provision for private automobiles in the RRT-city. The elevator would become a major transport mode as vertical travel is substituted for horizontal movement associated with lower density development. Most trips would have to include walking; thus, the person who could not walk some distance would be disadvantaged in the RRT-city, much as the non-driver is disadvantaged in the auto-city.

Comparison of significant characteristics of these two cities suggests that the total initial investment in housing and transportation would be significantly higher in the RRT-city. Therefore, the total annual cost per capita would be more nearly the same.

4.5 TRANSPORTATION CONSTRAINTS ON CITY SIZE

The desired nature, character, and lifestyle of the era are the principal decisions with regard to urban development. Various cities might differ widely in their pattern and intensity of development and still provide a high degree of mobility, at reasonable cost, for the urban resident. However, once the desired character for the urban area is identified, compatible land development and transportation policies must be evolved and implemented in a coordinated manner. Such compatibility and coordination must extend through the entire range of planning and implementation from broad planning concepts through the issuance of building and access permits.

Different urban transportation systems need and can accommodate different amounts and intensities of development in order to achieve economical operation. This, in turn, influences

the minimum and maximum functional size (land area and population) of an urban area. The number, size, and arrangement of focal points further influence the maximum city size that can be served by various modes of transportation.

With a well-designed system of arterial streets, a city can grow to sizeable proportions before a freeway system is needed for general urban mobility. With the auto as the primary mode of travel and maximum travel times of 40 to 50 minutes, a total urban area of 300,000 population might be served with the well-designed arterial street system and compatible urban development. As a city reaches this size, it also begins to approach constraints on the population that can be served by a single urban focal point, such as the central business district (CBD) which has historically been the area with the greatest level of development within most urban areas.

In most cities, walking is the principal mode of transportation currently used for circulation with the CBD. This limits CBD size to that which can be served by a pedestrian circulation system -- about one square mile.

The maximum number of persons accumulated within the CBD at any one time, usually at midday, is observed to vary with the population of the urban area. As the total population increases, the daytime population of the CBD also increases. Consequently, the type of transportation system needed to handle commuter traffic to and from the focal point varies with population. Based upon data from several existing cities, a relationship between city size, CBD population density, and urban transportation systems is presented in Figure 4.3.

Theoretical and empirical study data (5) indicate that cities with populations up to at least 300,000 persons and a corresponding CBD density of 50,000 persons per square mile (ppsm) might be served adequately by automobiles operating on arterial streets. If an extensive freeway system is provided to supplement the arterial streets, a total urban population of about one million surrounding a single principal focal point (with a corresponding density of about 130,000 ppsm) can be served by the automobile. For CBD population densities exceeding about 130,000 ppsm, additional modes are needed to supplement the pedestrian-based internal circulation system. Thus, larger urban areas must develop multiple focal points, or they must supplement both the automobile-based commuter system serving the principal focal point. The daytime population density in CBD's in cities appears to increase to about 100,000 ppsm before the intense development begins to spread out beyond the one square mile area. Then, both the size and the density of the CBD increase. The daytime population density of Manhattan Island has decreased in recent decades so that now it is about 500,000 ppsm. This might be considered

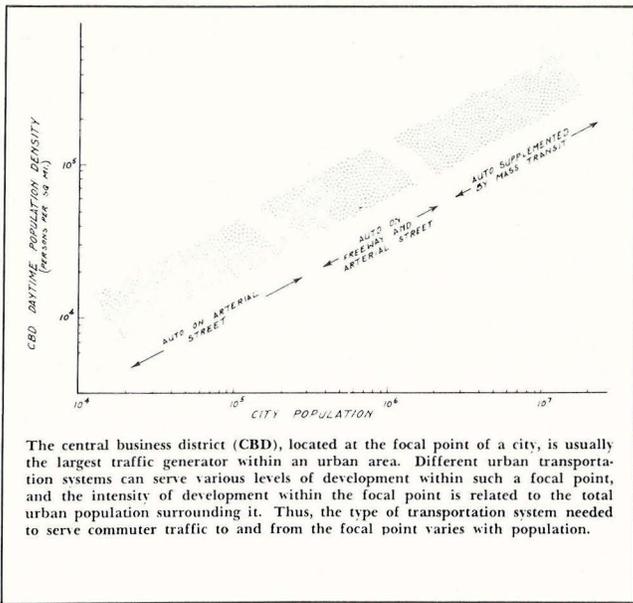


FIGURE 4.3 Maximum Urban Population Per Focal Point Served By Various Transportation Systems

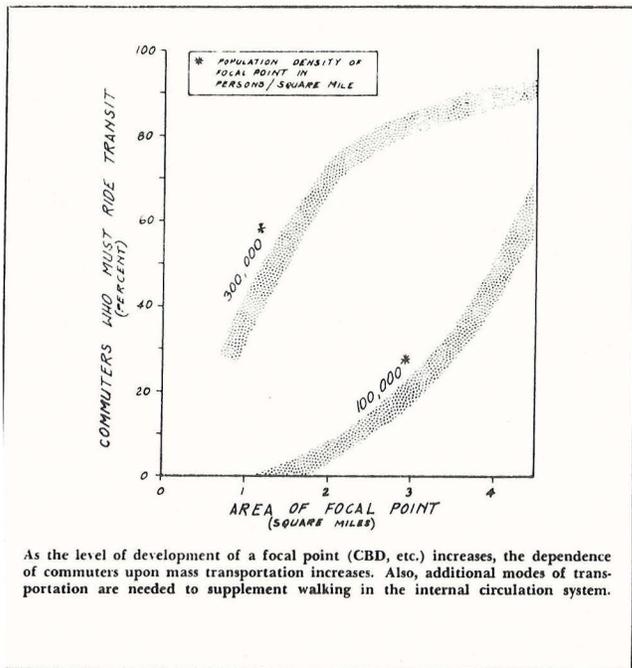


FIGURE 4.4 Importance of Mass Transportation to Highly Developed Focal Points

the maximum for modern CBD type development. As the level of development with the CBD is expanded beyond 100,000 ppsm and one square mile, the dependence upon mass transportation increases.

The percentage of daily CBD commuters that would have to use mass transportation is indicated in Figure 4.4 for various levels of CBD development. It is to be emphasized that the term "mass transportation" does not necessarily denote rail rapid transit. If 90 percent of the commuters to the downtown area are willing to ride transit to work, a total CBD daytime population of more than 1,200,000 persons might be served by the same fixed way facilities as for a CBD population of only 100,000 persons served by automobiles alone. However, the type and density of residential development, and hence lifestyle, would have to be radically different in order to deliver any significant number of the persons destined for the CBD by bus rapid transit.

Growing cities might avoid major transportation problems in the future if such relationships among urban size, form, and transportation systems are considered in the early stages of urban development plans.

4.4 INFLUENCE ON FUTURE DEVELOPMENT

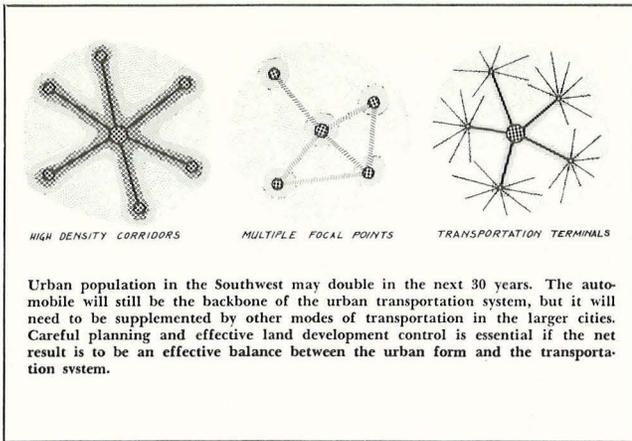
Total urban population is expected to nearly double in the next 30 years. Existing urban areas will not be abandoned. Therefore, this growth must be accommodated in a manner that is compatible with existing development patterns while, at the same time, accommodating new patterns.

Future transportation developments might be planned and the urban forms modified in accordance with one of the concepts illustrated in Figure 4.5. If a large proportion of future residents are willing to live in multi-family structures, urban forms resembling the high-density corridor concept can be developed in some cities.

The terminal concept might be implemented while retaining moderate densities of residential development in combination with larger, high density commercial centers. Parking facilities can be provided at remote and peripheral locations and connected to the major focal points by transit.

A multiple focal point concept of urban form can be created by limiting the development of any one focal point to that which can be served by private transportation. These focal points could then be connected by transit modes so that they could function much like a single concentrated area.

Other urban form concepts, as well as combinations of these, could possibly be developed as the urban population continues to increase.



However, careful planning and effective land management will be required to implement change successfully.

Local governments, through the use of police powers, have the ability to implement improved development practices which can protect the long-term utility of the transportation system (5, 6). These tools include the zoning ordinance, subdivision regulations, curb cut permits, building permits, use permits, occupancy permits, taxation, security and performance bonds, and various administrative procedures such as site development review. Effective use of these land use management devices must be made in a coordinated manner and with a clear understanding of the functional hierarchy of the street system or the interrelationships between the arterial streets and the adjacent land uses.

FIGURE 4.5 Urban Form Concepts for Mixed Transportation Systems

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DEMAND MANAGEMENT ALTERNATIVES

Sessions 5 through 9 of this course deal with the various transportation demand-oriented alternatives that may be implemented through transportation management processes to improve urban transportation. Demand Management is a relatively new term used to describe the processes of reducing the demand for transportation within a given system. The processes may take three basic forms: reducing the number of person trips; reducing the number of vehicle trips; or reducing the number of trips relative to time, or more specifically, spreading the peak period demands over a longer time period.

In some instances demand management may relate to transportation engineering technology, but largely, it is an element of business and industry management that has a direct bearing on transportation operations, and thus, an effect on transportation technology. Demand Management has a tremendous potential for the amelioration of transportation problems, but generally does not fall within the confines of authority of the transportation manager, except as it applies to employees within his own organization. Because the implementation of many demand management alternatives must be initiated by government, business and industry leaders, the success of these alternatives is largely dependent upon the management and leadership capabilities of the transportation manager. In other words, the transportation manager must convince others of the merits of demand management alternatives relative to urban transportation.

The five sessions relating to transportation demand-oriented alternatives include transportation pricing, peak period dispersion, ride sharing, improving public transportation, and bicycling as an urban transportation mode. Another session, Freeway Operations Management relates to the management of demand on a sub-system of the overall urban transportation system. It is also very strongly associated with traffic operational control to maintain the capacity of a facility. Therefore, it is included later as one of the sessions on capacity-related alternatives.

CHAPTER 5

TRANSPORTATION PRICING

SESSION OBJECTIVES:

1. *To introduce the concepts of consumer demand.*
2. *To investigate the effects of transit fare and service changes on ridership.*
3. *To explore the nature of the effects on auto usage that might be anticipated from price changes and parking controls.*
4. *To contrast different pricing concepts.*

5.1 INTRODUCTION

Transportation is generally recognized as a service and often is placed in the same category as police and fire protection, garbage collection, and public utilities. Short-term interruptions in the transportation industries occasionally highlight this aspect of transportation.

Transportation also has an important function in the production of economic wealth in combination with other factors such as (labor, materials, and capital). Transportation creates the utility of space and adds to the utility of time through increased productivity of business and industry.

Efficient transportation enables society to take advantage of the specialization of regional resources and division of labor so that a wide range of goods and services can be produced at the lowest total cost. The urban economy and the welfare of the urban citizenry are dependent upon the continued availability of efficient transportation. The application of pricing policies which reflect the cost structures of urban modes, therefore, are important in the management of the urban transportation system.

5.2 CONSUMER DEMAND

Although the exact shape of the demand curve for a specific item is rarely known, it is known that demand is inversely proportional to price (i.e., as price increases, demand decreases). Price elasticity may be defined as the percent change in quantity divided by the percent change in price. If total revenue is increased when price is decreased, the demand is "elastic" by definition; if not, the demand is defined as price "inelastic." The direct price elasticity is a measure of the sensitivity of demand to price change. The cross elasticity measures the sensitivity of demand

to a change in price of a substitute (e.g., the change in transit ridership as a result of a price change for auto use).

Transit fare elasticity, therefore, can be measured as change in transit ridership divided by the percentage change in fare. Transit service elasticity is similarly measured.

Income elasticity is a measure of the propensity for demand to increase or decrease with changes in income. Items such as automobile and air travel that exhibit positive income elasticity are "preferred" goods. Those that exhibit a negative income elasticity (such as public transit), are defined as an "inferior" good.

5.3 TRANSIT FARE AND SERVICE CHANGES

Changes in consumer behavior which occur over time complicate the problem of estimating elasticities using empirical data. Further, when fare and service adjustments are made simultaneously, as is often the case, it is usually impossible to isolate the effects of each. More attention in experimental design, when such changes are contemplated, would greatly contribute to the ability to analyze the impacts of future fare and service changes.

5.31 Fare and Service Elasticity. The evidence from various cities where transit fares have been changed indicates that transit demand is fare inelastic. John F. Curtin presented the first documented analysis based on patronage changes from a number of transit properties where fares were increased. This empirical study indicated that the average decrease in revenue was 33 percent of the change in fare.

In view of the fact that transit usage is negative income elastic, the apparent coefficient of fare elasticity might be expected to be smaller in response to fare decreases in an economy of increasing per capita income. This is supported by a recent investigation which indicated that, with the exception of one-car households, the preference elasticity of fare increases is twice that of a fare reduction.

More recent analyses of fare changes indicate that the systemwide average transit fare elasticity ranges between about -0.2 and -0.4 for total transit system riders. Based on recent fare reductions in Atlanta and San Diego average fare elasticity is estimated at -0.18 and -0.42, respectively (See Table 5.1).

Research also indicates that the fare elasticity

varies with trip purpose, income level, current level of transit service, and other circumstances.

TABLE 5.1 Fare Elasticities Estimated From Recent Fare Changes

City	Coefficients of Fare Elasticity	
	Arc (1)	Shrinkage Ratio (2)
<u>Fare Decreases</u>		
Atlanta	-0.18	-0.31
Cincinnati	-0.42	-0.73
St. Louis	-0.24	-0.34
San Diego	-0.42	—
<u>Fare Decreases</u>		
Rochester	—	-0.6
Buffalo		-0.25
Syracuse		-0.6
Albany		-0.5
(1) percentage of change in fare based on average of fares before and after fare reduction		
(2) Percentage change in fare based on fare before reduction		

TABLE 5.2 Elasticities of Transit Demand

	Trip Purpose	
	Work	Shop
<u>Fare/Cost:</u>		
Line-haul fare	-0.09	-0.32
Cost of accessing transit	-0.10	
<u>Service:</u>		
Line-haul travel time	-0.39	-0.59
Access travel time	-0.71	

Analysis by the Charles River Associates decomposed the elasticity by component of the trip as well as by purpose. As indicated in Table 5.2, this study found that a 10 percent decrease in transit fare would be expected to yield less than a one percent increase in work trips by transit (-0.9 line-haul fare elasticity). These elasticity coefficients also indicate that, while still inelastic, shopping trips are more sensitive than work trips to fare changes. The larger value of the service elasticity for the portion of the trip to/from the transit stop would stimulate ridership to a greater extent than the same improvement in line-haul travel.

5.32 Transit Fare Changes

The fact that transit ridership is fare inelastic suggests that an across-the-board fare reduction will not serve as a sufficient incentive, by itself, to cause significant increases in transit ridership or decrease auto usage. However, selective fare changes might improve the distribution of riders between the peak and off-peak hours.

Shopping trips are estimated to have a fare elasticity of over 3 times that of work trips. Therefore, reduced off-peak fares will have to shift from peak to off-peak periods. Such reduction in the peak period demand will permit more efficient use of rolling stock throughout the day and increased rider comfort in the peak. Where use is for non-work (such as in Toronto, where 30 percent of the trips in a.m. peak and 60 percent in the p.m. peak were estimated to be for non-work purposes), a sizeable number of riders might be encouraged to shift their time of travel.

Elderly persons also have been found to have a relatively high fare elasticity (-0.5). Therefore, off-peak reduced fares may be effective in shifting existing elderly riders to the off-peak as well as increasing the total number of elderly riders. Some 15 cities are experimenting with, and others are considering, no fare transit service during certain times of the day, within defined areas such as the CBD, or for special user groups such as the elderly or students. Selected examples are summarized in Table 5.3.

The magnitude of the fare elasticities make it evident that the added revenue from the increase in ridership will not be sufficient to off-set the reduction in total revenue resulting from the lower fares. In general, large fare reductions may be expected to require correspondingly larger amounts of public subsidy. However, in specific situations, the reduced fare, or no fare, program may increase system productivity and thus improve the revenue/cost ratio. These include:

- 1) No fare in the CBD or other highly congested areas where elimination of the delays resulting from collection of fares increases over-all speed and productivity so that fewer buses are needed -- These services offset the loss in revenue due to the no-fare program.
- 2) Reduced off-peak fare, or increased peak fares, where a significant number of non-work trips are made during the peak hour -- Reduction in the peak period demand and increase in the off-peak permits a more efficient utilization of labor and equipment. On routes with very short headways, the shift of some riders to the off-peak may permit a reduction in the number of buses necessary for the peak period pull-out.

5.4 PRICING AUTO USE

Various disincentives, such as controls on the location and availability of parking space, limits on parking duration, parking charges, and gasoline tax increases have been proposed at various times in order to influence auto use patterns.

5.41 Price Impact on Work Trips by Auto. The fact that automobile travel demand has a low price elasticity for work trips suggests that pricing mechanisms alone will have only limited success in affecting peak hour auto use. The price elasticity for out-of-pocket costs is estimated to be -0.07 for work trips. This indicates that a 50 percent increase in gasoline

TABLE 5.3 Summary of No-Fare and Reduced Fare Impacts on Transit Ridership and Diversion

<u>City</u>	<u>Type of Program</u>	<u>Results</u>
Seattle	CBD no fare zone. 105 square blocks, subsidized by city: September 1973.	Ridership increased on some lines in the area by 56 percent.
Dayton	CBD no fare zone. 66 block area; 1973.	14 percent increase in total transit ridership. 28 percent of this increase diverted from autos. Shift to long-term parking in peripheral areas.
Rockford	Senior citizens no fare program during off-peak hours. Subsidized 50 percent by State DOT and 50 percent by local revenue sharing funds; 1974.	100 percent increase in senior citizen transit ridership.
Atlanta	Systemwide reduced fare from 40¢ to 15¢. Funded by 1 percent sales tax. April 1973.	30 percent increase in total transit ridership, 50 percent of this increase diverted from autos.
San Diego	Systemwide reduced fare from 35¢ to 25¢. Funded from State gasoline tax; 1973.	22 percent in total transit ridership.
Los Angeles	Systemwide reduced fare from zone system fares as high as \$1.45 to a flat 25¢ rate.	22 percent increase in weekday transit ridership.

price can be expected to decrease the automobile demand for work trips by less than one percent. Furthermore, the cross elasticity with the cost of transit is zero, or very close to zero. This further indicates that increasing the cost of auto operation will have limited impact, if any, in encouraging people out of their automobile and onto transit. For example, the experiment with no-fare transit and the banning of autos from the downtown sections in Rome, Italy, resulted in a modest 11 percent increase in transit riders - automobile usage was not measurably affected.

Further, the price elasticity of gasoline (estimated at -0.10 to -0.15 in the short term and -0.30 in the long term) suggests that very substantial increases in price would be necessary to have a measurable impact on auto usage. A 100 percent price increase would stimulate a mere 10 to 15 percent decrease in short-term gasoline consumption and only 30 percent in the long term over which auto ownership and individual spending patterns might be adjusted.

The long-term gasoline price elasticity is probably overestimated as evidenced by European experience. If the gasoline price elasticity were -0.30, West German per capita gasoline consumption should be about 67 percent of that in the U.S., considering difference in real income, whereas actual per capita consumption is 84 percent of the United States consumption.

Other analyses indicate that auto use patterns are much more sensitive to fuel availability than to gasoline prices. It can be anticipated that consumers will attempt to off-set curtailed supplies or increased gasoline prices by purchasing smaller, more fuel-efficient autos for urban travel. The dramatic increase in small car demand during the 1973-74 oil embargo is evidence of such an adjustment in private transport investment. The resulting fuel savings will off-set the price increase; consequently, reduction in private auto travel would be modest. A dramatic price increase in gasoline, however, would be meaningful from the standpoint of conserving petroleum supplies.

The proposed federally-legislated 50 percent increase in auto fuel economy would be effective in reducing gasoline consumption by 40 percent. However, this increased fuel economy is also expected to stimulate a 10 percent increase in vehicle-miles of auto travel. A majority of this increase would undoubtedly be on the urban street and freeway systems in "off-peak" periods.

5.42 Parking Costs. Increased parking fees is a mechanism that is selective in its application; fees can be set at much higher levels in areas that experience congestion than in areas relatively free of congestion. There is also the advantage of an identifiable out-of-pocket cost, which an individual driver can associate with a particular trip. Therefore,

the impact is upon the cost of making specific trips in specific areas, while not affecting other areas where auto congestion is not a problem.

However, the use of parking fees as a pricing mechanism to change automobile use in high density, congested areas has some significant constraints. These include:

- Parking demand is inelastic with respect to price. The coefficient of price elasticity is estimated to be -0.30.
- A significant percent (15 to 50 percent) of the traffic in congested areas, such as central business districts, is through traffic.
- Typically, less than 20 percent of urban trips (less than 5 percent in large urban areas) are to the CBD where parking is not free.

Under these conditions a 100 percent increase in parking cost might yield a 15 to 25 percent restriction in traffic within the CBD.

Increased parking rates have the effect of discouraging long-term parkers and increasing the number of short term parkers.

However, the financial viability of a parking garage when the rate structure is altered to discourage long-term parking is a key question. Experience in areas of high parking demand indicates that long-term revenues either decrease or remain stable, while short-term revenues increase significantly. Therefore, a rate structure change to encourage short-term parking might prove to be financially sound.

5.5 PRICING CONCEPTS

Pricing charged for transportation, relative and absolute, might be used to influence the demand for transportation in terms of the total magnitude, the geographical distribution, the temporal distribution, and the distribution between the types of urban transportation. The philosophy under which the pricing system is developed and administered is of major significance if the price mechanism is to be used in reducing peak period travel. The various pricing schemes may be described as arbitrary, rational, or incentive.

5.51 Arbitrary Pricing. Price is largely unrelated to the cost involved in providing the transportation. Blanket increases in prices and freight rates based on the value of the commodity are notable examples of this approach to pricing. Application of an arbitrary pricing scheme is simple in that knowledge of the total revenue derived is the only information needed. However, misallocations in the use of resources will result from application of arbitrary pricing.

5.52 Rational Pricing. Price is established according to the actual fully-distributed costs of providing the transportation service. In establishing freight rates this approach is commonly referred to as "cost-based pricing." Application of a rational pricing system requires that the cost structure be known for the specific conditions involved. Costs will differ with a combination of variables, such as: peaking characteristics, vehicle occupancy, volume of traffic, ratio of fixed to variable costs, directional imbalance in demand in peak periods, and the time period used in the analyses.

Typically, the cost per passenger-mile for fixed route systems, such as RRT, is sensitive to the volume of traffic. Increased volumes provide a larger base for distributing the high capital costs associated with such systems. As an example, the cost per passenger-mile at a volume of about 6,000 passengers in the peak hour is approximately one-half that at a peak hour volume of 2,000 passengers. The reduction in unit cost (cost per passenger-mile is relatively modest with increases in volume above 10,000 to 12,000 passengers in the peak hour. The unit cost of bus transportation, on the other hand, is rather insensitive to increases in volume. This results from the fact that buses can share the traveled way with other vehicles and that most of the costs involved are variable so that marginal cost and average cost are nearly the same. Additional traffic simply means the addition of buses, each of which has a cost per mile that is essentially the same as the total average cost.

All forms of urban transport are sensitive to the distribution of traffic between the peak and off-peak periods. However, the proportion of the traffic carried in the peak varies considerably (about 10 percent for arterial streets and freeways, 15 to 25 more for RRT). Therefore, the costs associated with un-utilized capacity in the off-peak contributes a greater incremental increase to the unit cost per passenger-mile in the case of RRT than for auto.

5.53 Incentive Pricing. This pricing mechanism might be employed to encourage given consumption patterns and to discourage others; such application may be described as incentive pricing. To be effectively employed, the following information must be available:

- Definition of the total cost structure of the forms of transportation and the related facilities.
- Knowledge of consumer demand in response to price changes.
- Specific, well-defined objectives to be achieved by the incentive price scheme.

A variety of price changes might be used in combination to mold consumer demand in the

desired direction. For example, parking rates may be increased to discourage long-term parking in congested areas in combination with reduced transit fares. Commonly, service charges (such as improved frequency of transit service, preferential frequency of transit service, preferential frequency of buses, etc.) also will be involved in an incentive pricing program.

5.54 Congestion Pricing. In the mid- and late-1960's, the topic of congestion pricing on urban streets received considerable attention. The basic concept is simply to establish a fee structure for the use of specific street facilities. Such a pricing approach would work as a disincentive since the greater the traffic demand and resulting congestion, the higher the fee for the use of that section of street.

Proposals for congestion pricing during peak periods are predicated upon the incremental costs associated with building capacity to meet peak period demand when the capacity is not needed at other times of the day. A similar rationale applies to pricing according to environmental impact, energy consumption, and other societal costs associated with traffic congestion.

Such a pricing mechanism of course, presumes that willingness or ability to pay is an appropriate measure of the social priority that should be placed on an individual trip. While the theory of congestion pricing is relatively simple, the practical and administrative realities make general application a remote possibility. However, in specific limited situations, such as tunnels and bridges leading to congested areas, it may be a practical approach.

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CHAPTER 6

PEAK PERIOD DEMAND MANAGEMENT

SESSION OBJECTIVES:

1. *To introduce to the Transportation Manager the concept of peak period demand management.*
2. *To describe briefly the peak period demand dispersion alternatives, and to point out the advantages, disadvantages and potential of each of the alternatives.*
3. *To suggest implementation guidelines for peak period demand management.*

6.1 INTRODUCTION

Most urban transportation systems operate satisfactorily during 20 to 22 hours of the day. It is the 2 to 4 remaining hours of the day in which the "wheels of progress" turn more slowly. The congestion, delay, and other operational deficiencies are the direct result of transportation demand exceeding the supply during those hours. Unfortunately, an urban transportation system is judged on its sufficiency during those peak hours rather than the remainder of the day. Then conceptually, the urban transportation system may be improved if some of the peak period demand is dispersed to other hours of the day when the transportation supply exceeds the demand.

It is a well documented fact that peak period travel is largely made up of work trips. Congestion occurs because of the coincidence of these trips, or everyone attempting to satisfy a common work schedule. Thus, changing the work schedule is one approach to reducing congestion. Two general concepts for changing work schedules have been used with varying degrees of success. These are:

6.11 Shorter Work-Week. This concept is based on re-scheduling the normal work week to longer hours per day, but fewer days per week. For example, four 10-hour days. Such a schedule could move the work trip to one hour before the a.m. peak and one hour after the p.m. peak, and reduce the number of work trips.

6.12 Variable Work Hours. This concept is based on processes of varying the starting and quitting times of employees relative to the peak periods to reduce the coincidence of work trips. Typical of this concept is "staggered work hours," where groups of

employees may have work schedules beginning at 7:00, 7:30, 8:00, and 8:30 a.m., and quitting times of 4:00, 4:30, 5:00, and 5:30 p.m., respectively.

6.2 SHORTER WORK WEEK

6.2.1 The concept. In recent years, there has been an upsurge of interest in the 4-day work week. Generally, employees work four 10-hour days and have three days of leisure; however, work days are not necessarily consecutive. Also, some firms have adopted three 12-hour days as a specialized work schedule. In most instances the shorter work week relates to routine jobs with little personal reward. The objective is to minimize the boredom of the job and maximize the personal interests. The shorter work week is a worthy consideration, but there are advantages and disadvantages.

Advantages. The shorter work week has demonstrated improved morale, principally because it affords the worker more free time. Employees use this free time in various ways -- more leisure, travel and "moonlighting" to increase personal income. At any rate, the improved morale generally results in reduced absences, improved productivity, and greater profits for the employer.

From the transportation standpoint, the shorter work week could, at least conceptually, reduce travel demand. Further, there is a very positive potential for peak period dispersion, provided only part of the total work force is on the shorter work week. The 10-hour day is normally scheduled to begin earlier and end after the normal 8-5 schedule.

Disadvantages. The disadvantages of the shorter work week are related to business interests and transportation interests. First, there is the problem of more complex management. Scheduling employee groups requires a greater management staff, and thus, increases the cost of operation. From the transportation standpoint, there is a potential increase in overall travel. Employees who seek additional employment continue to travel. Those pursuing leisure time activities are frequently engaged in more frequent and longer trips as a result of increased leisure time. Also, there is the possibility of increased auto usage because of the relatively uncongested conditions before and after the peak period. However, this possibility exists for all of

the variable work hours alternatives.

6.22 Potential for Acceptance. There is, in fact, a substantial application of the 4-day work week at this time. Organized labor is only lukewarm to the idea, but the laborers themselves seem to favor the concept. Labor leaders favor a 4-day week, but with a reduction in the number of hours. It is interesting to note that the new policy of shifting holidays to Monday will result in 10 4-day weeks for most workers.

William W. Nash, Jr., has predicted that 35 to 40% of the work force will be on 4-day work week by 1990. He bases his prediction on the current trend of acceptance, and on the evolution of the work week from the 6-day week to the 5-day week. He points out that the transition from a 6- to 5-day week began about 1920 and by about 1940, the 5-day week was common practice. Allowing the same 20 year transition period, the 4-day work week could be common practice by 1990 (3). It is interesting to note from projection of this 50 year cycle, we will be down to a zero day work week in the year 2190!

6.23 Possible Arrangements. The arrangement of the business operation relative to the 4-day work week has a very significant effect on transportation demand. The table below indicates, according to Nash, the percent decrease in peak traffic demand dependent upon whether the work force is spread over a 4, 5, or 6 day operating schedule. These values are based 35% of the work force being on a 4-day work week.

Weekly Schedule	Percentage of Employees on the Job on a Given Day						% Decrease Peak Traffic Demand
	M	T	W	T	F	S	
4-Day	100	100	100	100			8
5-Day	80	80	80	80	80		15
6-Day	67	67	67	67	67	67	21

6.24 Potential Transportation Effects. These are categorized as follows:

Shift and Dispersion of Peak Period. The benefits depend on the percentage of the work force on the 4-day schedule, and whether the overall operating schedule is 4, 5, or 6 days. The greatest benefit is derived from the 6-day operating schedule.

Increased Auto Usage. Shifting part of the peak will relieve congestion which, in turn,

may increase auto usage. The opportunity for car pooling, however, should not be reduced to any great degree. Auto usage could be expected to increase due to greater opportunity for independent activity. This would contribute to an increase in overall travel, but not necessarily peak hour travel.

Increased Leisure Travel. It is fairly conclusive that leisure travel will increase, because this seems to be one of the stimuli to the trend. However, most of the travel should occur during the off-peak periods, and on the rural facilities.

6.3 VARIABLE WORK HOURS

6.31 Forms of Variable Work Hours. Variable work hours take two basic forms: "staggered hours" and "flexible hours."

Staggered Hours. An arrangement where subgroups of a total work force operate on a fixed schedule, but the starting times of the subgroups are staggered to constitute a variable starting time for the total work force.

Flexitime. An arrangement where individual employees establish their own schedule within specific guidelines or regulations. A typical arrangement may be described as follows: An employee may begin work any time between the hours of 7 to 9 a.m. and correspondingly end the work day between 4 and 6 p.m. Some agencies permit a variable lunch hour between the hours of 11 and 2. Thus, 7 to 9, 11 to 2, and 4 to 6 are flexible hours and 9 to 11 and 2 to 4 are core time when all employees are required to be at their work stations.

6.32 Applications of Variable Hours. The selection of "staggered hours" or "flexible hours" is dependent upon the characteristics of the organization, the nature of the work, and size of the work force.

● Staggered hours. This method is generally applicable to large organizations with several major subgroups that have a certain interdependence due to the nature of the work they perform. Typical examples are assembly line processes, industrial plants, and others. Staggered hours is particularly applicable to shift work where a plant operates 24 hours per day.

Staggered work hours is practiced extensively in government offices in Washington, D.C., even though there is little public mention of the fact.

● Flexible hours. This method is applicable to smaller work forces and even larger ones where workers are less dependent upon others for the accomplishment of the work

task. "Flexitime" has been used extensively in administrative offices in the United States and European countries. Also, the system has been adopted in many light manufacturing industries in Switzerland and Germany.

Flexitime is particularly adaptable to professional work forces.

6.33 Examples of Variable Work Hours. The various forms of variable work hours are now employed in various parts of the world. The staggered hours system has been adopted, as a matter of necessity, in large aircraft plants such as General Dynamics in California and the auto industry in Detroit. These applications are typically 24-hour operations. Applications to single shift normal work day operations are not quite as common. The effects of variable work hours on urban transportation systems were studied in two major projects: the Lower Manhattan Staggered Work Hours Project, and the Ottawa Experiment.

6.33.1 Lower Manhattan Staggered Hours Project. On April 1, 1970, about 50,000 employees of some 50 organizations in Lower Manhattan voluntarily changed their work hours in a closely monitored program to determine whether such work schedule changes would help relieve peak-hour transportation congestion. The results were positive, with reductions in peak travel demand, and favorable acceptance by most of the employees.

In 1969, prior to the major effort, the entire managerial and clerical work force of the Port of New York Authority, some 2,400 persons, participated in a 4-month staggered hours project as a pilot study. In this study, the work force was divided into thirds with one-third maintaining the normal schedule of 8:45 to 4:45. One third was assigned to a schedule 30 minutes earlier (8:15 to 4:15) and the other 30 minutes later (9:15 to 5:15).

Employee acceptance studies indicated some problems, but the general acceptance is significant. A survey of employee attitudes revealed the following:

<u>Reaction</u>	<u>Percent</u>
Strongly Favorable	29.8
Somewhat Favorable	39.1
Somewhat Unfavorable	21.7
Strongly Unfavorable	9.4

To test the effects of the pilot study on congested conditions, observations were made of arrivals relative to time in the lobby of the Port Authority Building. Figure 6.1 shows the reduced congestion and the spread of the peak period as a result of staggered hours in the pilot project.

Based on the favorable results of its internal study, the Port of New York Authority suggested to the Downtown-Lower Manhattan Association that a project be undertaken to test the effects of staggered hours on a large scale. The Downtown-Lower Manhattan Association agreed to a cooperative project with the Port Authority in February 1969. A survey was conducted to determine to what extent staggered hours were being used in the Downtown-Lower Manhattan area. The results (Figures 6.2 and 6.3) show a very pronounced singularity in the 9:00 to 5:00 work schedule.

A promotional campaign for the staggered hours project was begun in 1969, with letters from the president of the D-LMA transmitting results of the staggered work hours survey and soliciting the cooperation of its members in the proposed project. An example of the D-LMA promotional campaign is given in excerpts from a letter as follows:

On February 19, 1969, I sent to each member of the Association a questionnaire designed to gather information on the work schedule practices of firms in Lower Manhattan. This questionnaire constituted the first important phase of what we felt should be a new survey and effort to design and implement a workable staggered hours program in this area....

Some 113 of our member firms responded to this questionnaire, and the results have now been analyzed by the Port of New York Authority. As you will read in the enclosed report, the problem of concentrated peak hour congestion has not been eased at all since the D-LMA first advocated staggered work hours in the early 1960's....

All of the members of the Association are aware that we are pushing as hard as possible to have additional subway facilities provided in lower Manhattan. Even the most optimistic of us know, however, that the Water Street subway is a least 8 to 10 years away. In light of this, we feel strongly that the only practicable solution to our terrible peak hour problems is the concept of staggered work hours....

In the last few weeks, the officers and Planning Committee of the Association have been discussing with representatives of the Port Authority the possible future steps we could take toward implementing staggered work hours in lower Manhattan. Because of the Port Authority's interest in this concept, they conducted an experiment in their own organization. The report of their findings and conclusions is enclosed. The results show that Port Authority operations and employee morale were not adversely affected by staggered work hours. In fact, more than 40 percent of the Port Authority

ARRIVAL TIME AND NUMBER OF PERSONS
ENTERING PORT AUTHORITY BUILDING LOBBY
PERSONS

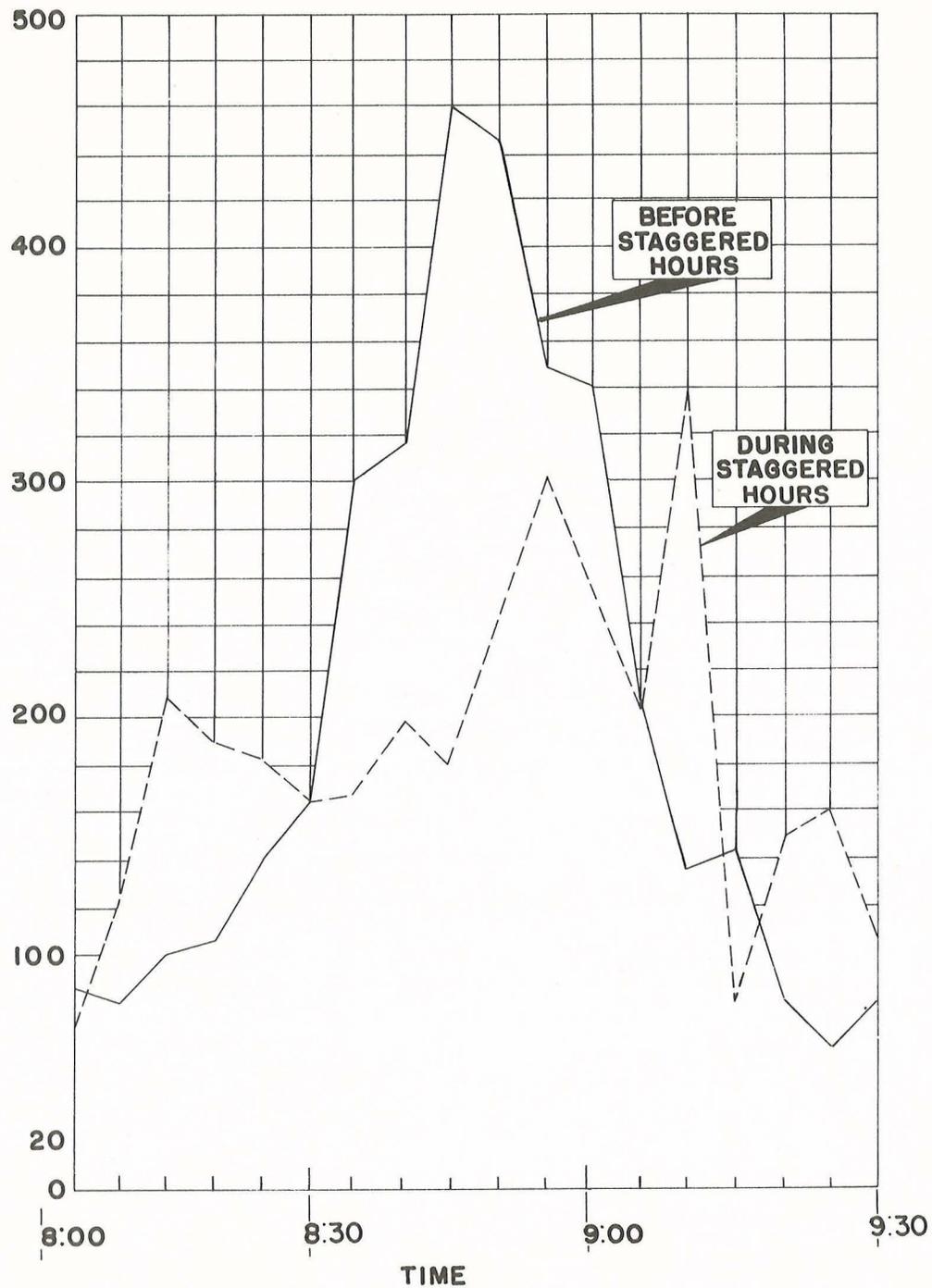


FIGURE 6.1. EFFECTS OF STAGGERED HOURS IN PORT AUTHORITY STAGGERED
WORK HOURS PILOT PROJECT

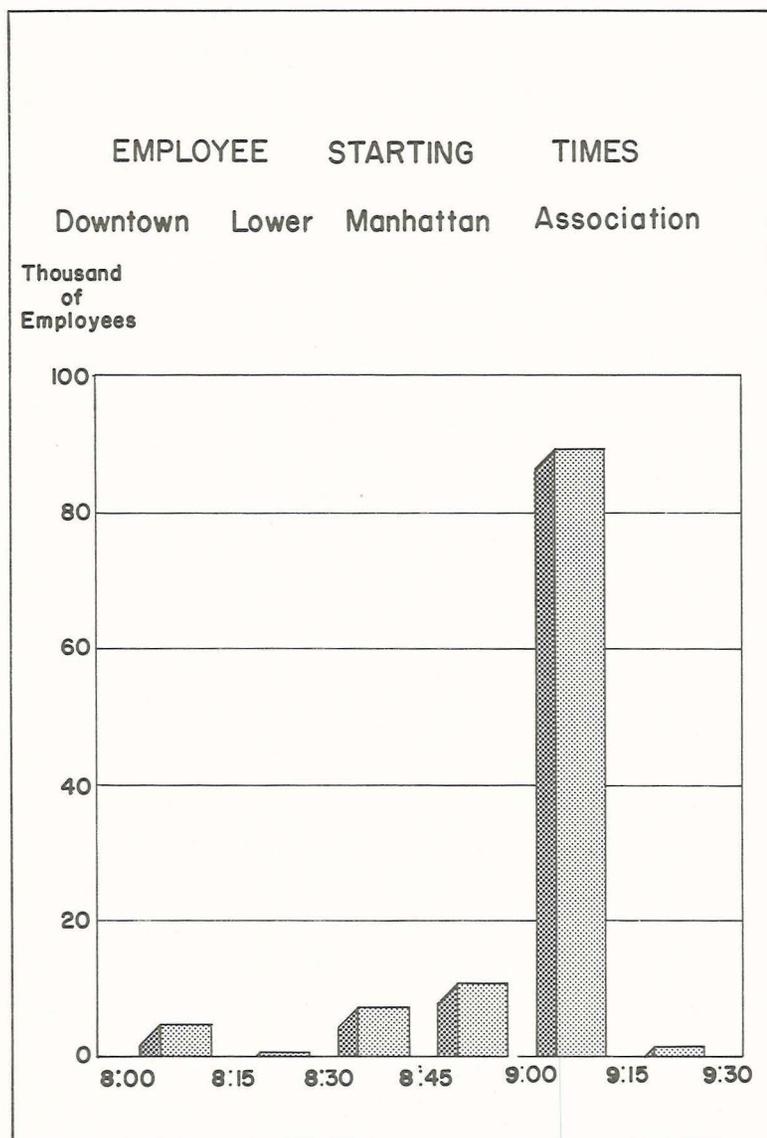


FIGURE 6.2. EMPLOYEE STARTING TIMES, DOWNTOWN LOWER MANHATTAN

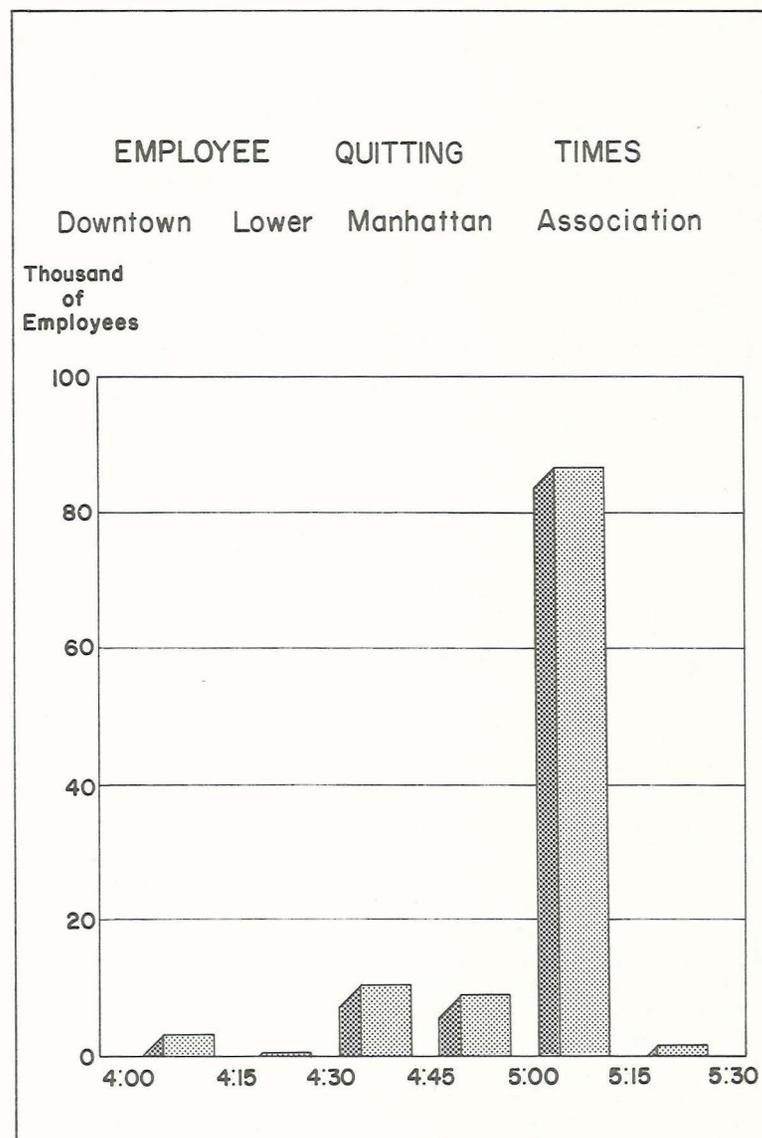


FIGURE 6.3. EMPLOYEE QUITTING TIMES, DOWNTOWN LOWER MANHATTAN

headquarters' employees have remained voluntarily on staggered work hours after the formal experiment ended....

Our present thought is to enlist about 100,000 employees of as many firms as possible to participate in a six-month experiment working on an 8:30 a.m. to 4:30 p.m. schedule, which we would hope could begin early next year. A task force comprised primarily of John Goodman, D-LMA's Executive Vice President, and Roger Gilman, Director of the Port Authority's Department of Planning and Development, will be getting in touch with some of you within the next few weeks to discuss the proposed six months experiment. I would hope that the firms who are contacted will cooperate to the maximum extent possible. If you should not be contacted and wish to undertake such an experiment, please feel free to do so; however, it would be appreciated if you would advise the Association so that your experiences and findings would be part of the overall results.

During the experiment, this same task force of D-LMA and Port Authority representatives will ask the management of the participating firms to report the effect of the experiment on the output and efficiency of the firms and on the morale of their employees. After assessing the effects of the experiment, the task force would recommend to the D-LMA Board of Directors whether staggered work hours should be further expanded.

To some of you, I am sure that staggered work hours is an old story, often talked about but seldom if ever tried in a systematic and meaningful way. Because of the transportation crisis we are now facing, however, I am confident that this new attempt can and must be far more successful than past endeavors. I am convinced and so are members of the Planning Committee that the concept of staggered work hours is the only solution over the next decade which can provide more comfortable commuting for the hundreds of thousands of men and women who travel into and out of Lower Manhattan every working day.

A series of meetings with principal industry groups in Lower Manhattan was held early in 1970 to identify the problems and explain the proposed solution. The project was officially begun April 1, 1970.

The effects of staggered hours on transportation facilities were measured by passenger counts on Port Authority Trans-Hudson (PATH) and New York City subways in March and June 1970. Indications are that significant effects had taken place. Before and after passenger counts are presented in Figure 6.4 and Table 6.1.

According to news media reports in 1972,

the participation in the staggered hours project had increased to 255 business firms and public agencies, and 89,000 workers. It is reported that congestion on the three major subway lines and the PATH system in Lower Manhattan has decreased 26 percent during the morning peak travel period. A study is now in progress to extend the staggered work hours program to mid-town.

6.33.2 Ottawa Variable Work Hours Project.

On March 4, 1973, approximately 33,000 government workers in the central area of Ottawa went on a variable work hours program. This project involved almost 50% of the total 70,000 workers in the central area. The program consisted of a broad combination of staggered work hours (15 minute intervals) and Flextime. A detailed report of the project is published in the March 1975 issue of Traffic Engineering. The project was implemented by federal agencies and departments as a result of a serious over-taxing of the bus transit system.

The effectiveness of the project was measured by observations of bus ridership and traffic volumes at various screenlines around the area, and by observations of the arrival and departure times of vehicles at major parking lots in the area.

As shown by Table 6.2, there was no appreciable change in modal split as a result of the variable work hours project. In fact, it is encouraging that there was not an increase in auto usage.

Table 6.2

Comparison of Modal Splits
(Auto-bus) Before and After Introduction
of Variable Work Hours Program

	MODAL SPLIT	
	Before	After
A.M. peak (7-9:30)	50/50	47/53
P.M. peak (3-6)	57/43	55/45

Bus ridership was improved appreciably as a result of the variable work hours project. Figure 6.5 shows a before and after comparison for one screenline checkpoint. Considering only the peak 15-minute period, inbound demand was reduced 21 percent and outbound demand was reduced 29 percent.

Automobile traffic counts at screenlines showed significant changes as illustrated

Table 6.1
Changes in Patronage at Three Lower
Manhattan Stations

Beginning of 10-Minute Period	Passengers During Peak 90 Minutes (Rounded to Nearest Whole Percent)		
	Before Project	During Project	Change
Morning Passengers Leaving Trains (75,900 Passengers)			
8:00	6	5	-1
8:10	9	8	-1
8:20	8	10	+2
8:30	11	14	+3
8:40	14	15	+1
8:50	20	18	-2(-1,370)
9:00	18	12	-6(-4,650)
9:10	9	10	+1
9:20	5	8	+3
Evening Passengers Boarding Trains (53,700 Passengers)			
4:00	5	4	-2
4:10	5	6	+1
4:20	6	7	+1
4:30	11	12	+1
4:40	11	12	+1
4:50	17	15	-1(-1,360)
5:00	21	19	-2(-1,170)
5:10	14	15	+1
5:20	10	10	0

6-7

EFFECTS OF STAGGERED WORK HOURS ON
PASSENGER VOLUMES AT PATH HUDSON TERMINAL

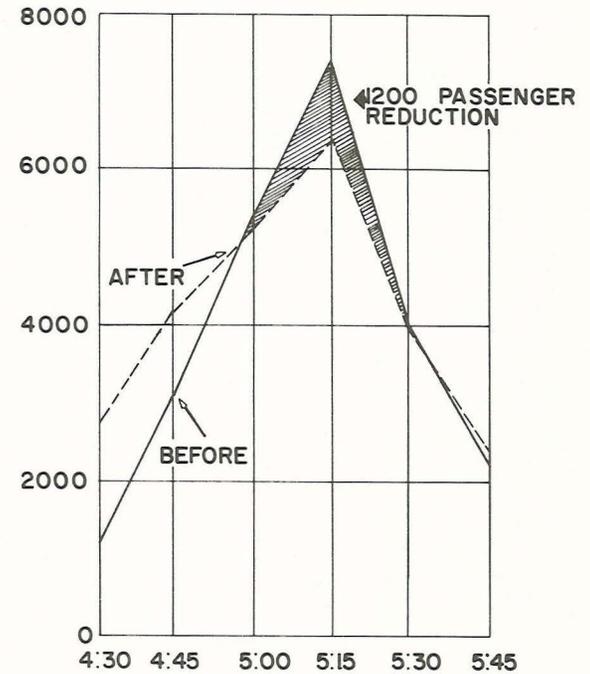


FIGURE 6.4. EFFECTS ON PASSENGER VOLUMES AT PATH HUDSON TERMINAL,
DOWNTOWN LOWER MANHATTAN STAGGERED HOURS PROJECT

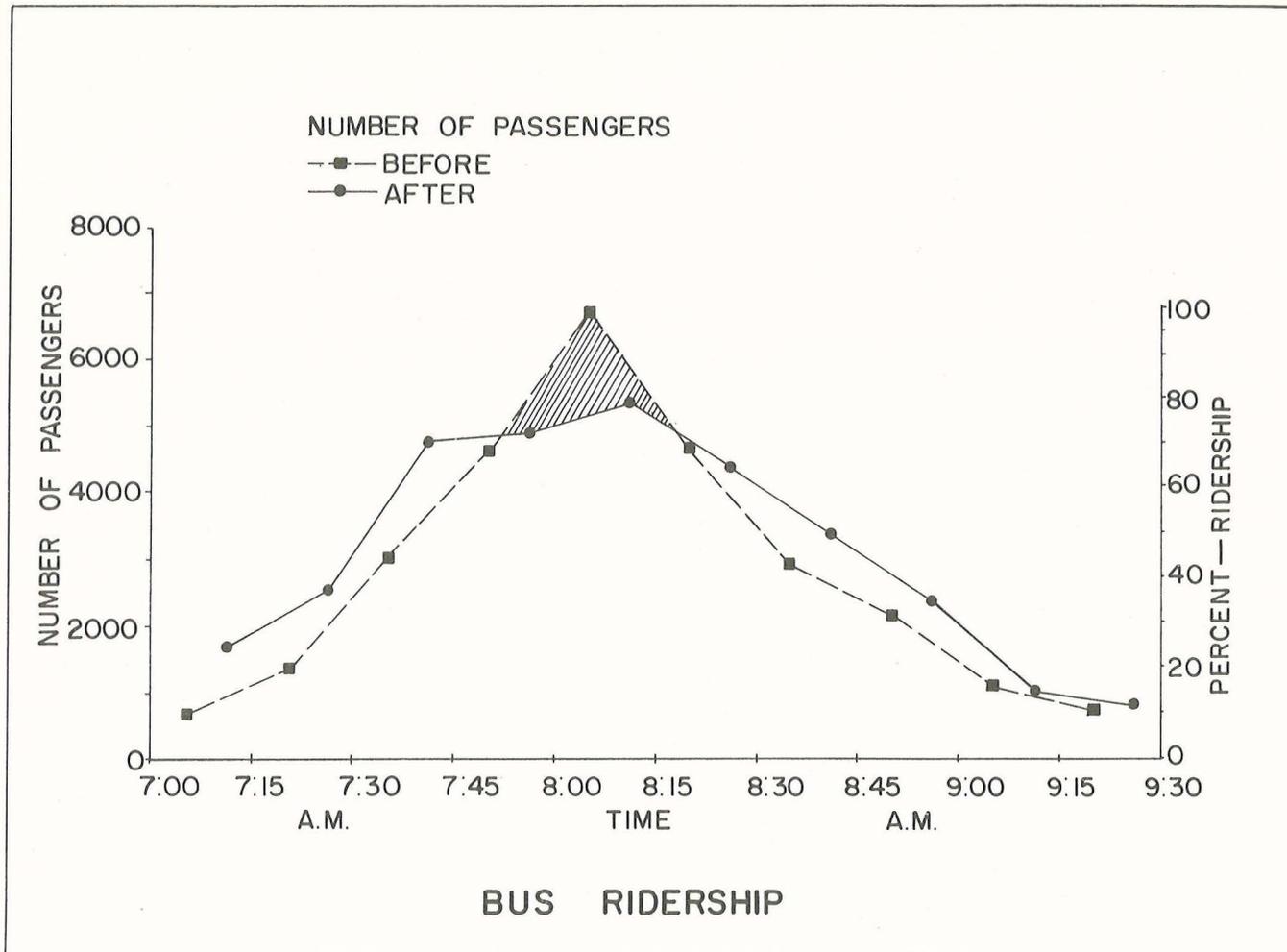


FIGURE 6.5. BEFORE AND AFTER COMPARISON OF BUS RIDERSHIP, OTTAWA VARIABLE WORK HOURS EXPERIMENT

in Figure 6.6. Although there was an overall increase in peak period volumes, the peak 15-minute volumes were reduced. Figure 6.6 shows a definite "broadening" effect of both the a.m. and p.m. peaks.

The effect of variable work hours on parking is best illustrated by Figure 6.7, a presentation of arrivals and departures by 15-minute periods. It is noted that 15-minute peaks are reduced, and the peak periods are broadened substantially. It is concluded that the variable work hour project has been successful in reducing congestion. Peak traffic periods (15-minute) are reduced, transit is less crowded and ridership is increased, and, in general, the peak period is dispersed.

6.33.3 Pitney-Bowes Experiment. In August 1974, Pitney-Bowes Corporation of Stamford, Connecticut initiated an experiment with Flextime involving 220 employees. Employees were permitted the selection of a work schedule within the hours of 7:00 a.m. to 6:00 p.m., with a core time of 3½ hours. The experiment has resulted in increased employee morale and reduced absenteeism. Based on their experience, and barring any "novelty" effects, Pitney Bowes estimates reduced absenteeism to be one hour/employee/month. Equated to 2000 employees at an average rate of \$4.16 per hour, the annual time savings is approximately \$100,000.

$$\text{Annual Time Savings} = (1 \text{ hr/mo})(12 \text{ mo/yr}) \\ (2000 \text{ employees})(4.15/\text{hr}) = \$99,600$$

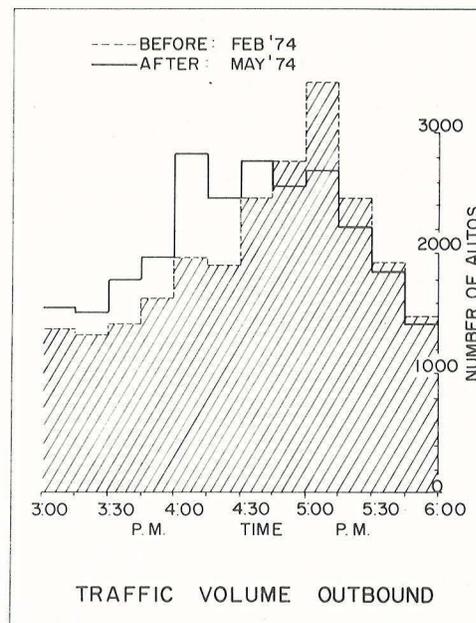
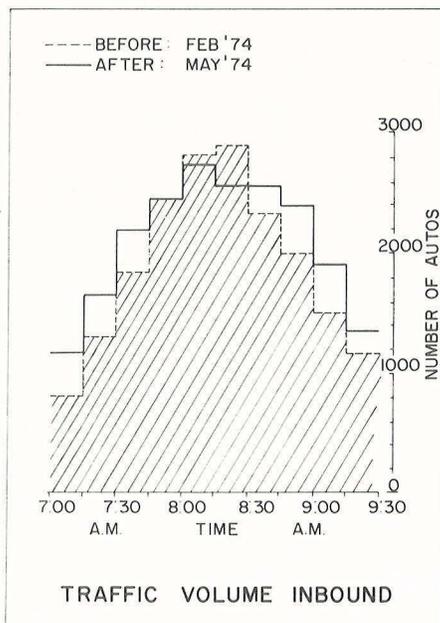


FIGURE 6.6. BEFORE AND AFTER COMPARISON OF TRAFFIC VOLUMES, OTTAWA VARIABLE WORK HOURS EXPERIMENT

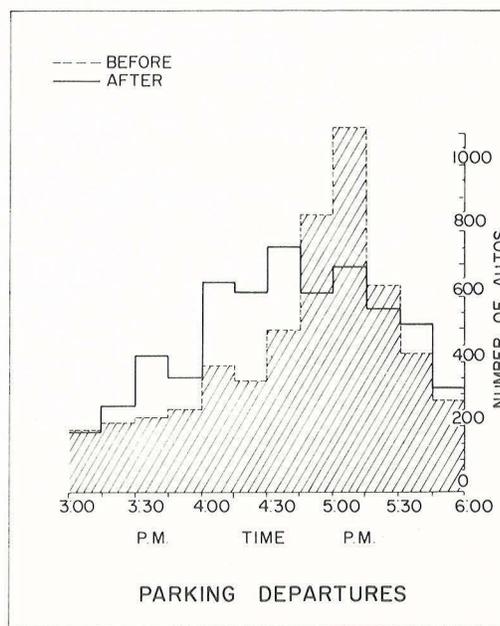
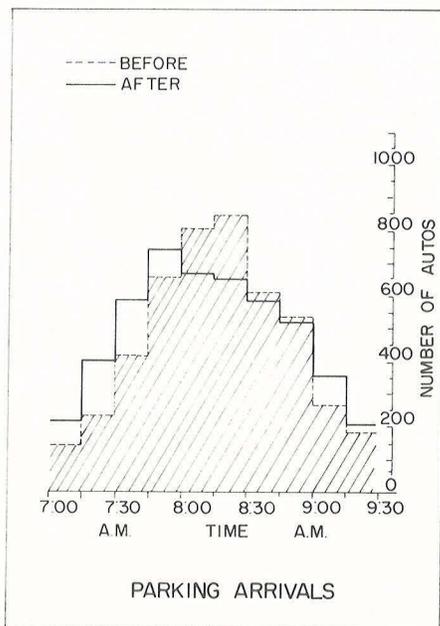


FIGURE 6.7. BEFORE AND AFTER COMPARISON OF PARKING ARRIVALS AND DEPARTURES, OTTAWA VARIABLE WORK HOURS EXPERIMENT

6.4 IMPLEMENTATION GUIDELINES FOR DEMAND MANAGEMENT

The transportation manager has very little direct authority for implementation of demand management. Therefore, he must exercise leadership capabilities to bring about improved transportation through the implementation of demand management alternatives by others. Leadership capabilities are enhanced greatly by following, at least in a general sense, these guidelines.

Unified Approach. All transportation resources within an urban community should be under the direction of a common agency, or at least coordinated through common objectives and commitments. One convenient agency may be the Metropolitan Planning Organization as required in the transportation planning process.

Determine the Potential of Demand Management. This potential is dependent on the characteristics of principal work forces. For example, heavy industry, light industry, commercial and administrative work forces have different requirements and thus different potentials.

Develop Factual Data. Be able to point out the benefits of demand management in terms of savings in time and money, employee morale, and in better utilization of transportation resources.

Develop Alternative Plans. Offer the business and industry interests alternative solutions, along with estimates of cost-effectiveness and trade-offs.

Promote a Cooperative Effort. Transportation problems no longer can be solved by a single agency, because the solutions to the problem do not fall within the confines of a single agency. It is necessary to enlist the cooperation of business, industry, labor unions and the labor force. The cooperative effort of the Downtown-Lower Manhattan Association and the Port of New York Authority is a prime example.

Continuing Communication. In the implementation of any transportation improvement alternative, continuing communication is necessary for success. This is particularly critical in demand management because there are so many factions involved.

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CHAPTER 7

RIDE SHARING PROGRAMS

SESSION OBJECTIVES:

1. *To explore various methods of increasing vehicle occupancy.*
2. *To identify considerations in the implementation of ride sharing programs through the use of case studies.*
3. *To identify the effects of ride sharing programs on other transportation improvement programs.*

7.1 INTRODUCTION

If we may assume that there are a fixed number of person-trips that must be accommodated by an urban transportation system, then one obvious method of reducing the vehicular demand on the system is to increase the number of person-trips per vehicle. This session presents a number of alternatives for increasing vehicle occupancy through ride sharing programs. These include:

- Carpools
- Vanpools
- Shared Ride Taxi
- Jitneys
- Subscription Bus Service

There are some concerns that such programs may reduce transit usage; for example, the prime prospects for carpooling may be those same individuals who have the highest potential to ride transit. Further, improved traffic operations on the transportation facilities may result in an increased number of person-trips. There is sufficient reason for concern that the transportation manager must weigh meticulously the impacts of some improvement programs on other existing and successful programs.

7.2 CARPOOLS

In the late 1960s and early 1970s (prior to the energy crisis) carpool promotion was not widespread, although there was "considerable talk" and various attempts were made at encouraging carpooling. Most organized carpool programs were promoted by individual employers to benefit their employees; only a few of these programs were successful. Such successes that occurred were motivated by substantial parking shortages on the employment site or severe traffic congestion in the vicinity of the site.

Automobile occupancy, as measured in the

Nationwide Personal Transportation Survey, collected in 1970 by the Bureau of the Census, indicated that the national average automobile occupancy for work trips was approximately 1.4 persons per car. As indicated by the several urban transportation studies which have been performed in urban areas with over 50,000 population, work trip occupancies have been observed to range from about 1.1 to 1.6.

Carpool matching is the most widely applied promotional activity and various computer programs, such as the one available from the Federal Highway Administration, have been prepared to facilitate this matching process. Carpool or buspool matching is based on the hypothesis that the major deterrent to the formation and use of carpools or buspools is a lack of knowledge relative to origin, destination and time of travel of other persons making trips between the same places at the same time.

While computer techniques have captured much of the attention, it should be recognized that, while adding a great deal of technical sophistication, computerization does not influence the basic reasons why people do or do not form carpools. The matching of persons in the carpool can be accomplished manually. The Hallmark Card Company, for example, used manual procedures at its Kansas City plant which employs some 4,500 persons. The report, Manual Carpool Matching Methods, presents techniques that can be employed to organize and manage carpool matching. Manual procedures might be employed on a permanent basis (especially by smaller firms), or used as the initial step for large employers that later switch to computerized techniques.

When computer matching is employed, it is desirable that all organizations in the same area adopt the same program, or at least use a common data format. This will permit merging and separate data files so that individuals employed by different firms located in the same small employment area might be matched into common carpools. Various incentives involving cost, travel time, convenience, or a combination of the three, might be employed to encourage carpools. Examples of selected successful carpooling programs include the following.

- Prudential Insurance Company, Boston. Employees who carpool in groups of three or more are provided free parking in a company-owned garage. The normal parking fee is \$2.50 a day. Over 40 percent of the employees

are presently in carpools and the demand for free carpool space is approaching the supply.

- Port of Portland, Portland, Oregon. The Port of Portland initiated a variety of incentives for encouraging carpools and transit usage by its 300 employees in December 1973. The Port pays the \$10.00 monthly parking for carpools of three or four persons. For carpools of five or more persons, the Port pays the \$10.00 monthly parking charge plus \$0.11 per mile. Transit users are paid up to \$0.70 per day. Approximately 25 percent of the Port's 300 employees are taking advantage of these incentives. The use of public funds to subsidize commuting costs has become a topic of controversy and the program is the subject of some criticism.

- Texas A&M University. In the Fall of 1974, faculty, staff, and students of Texas A&M University were provided the option of organizing carpools of 3 or more persons, with each paying \$4.00 per year for parking on campus. A regular parking fee is \$48.00 per year per vehicle. Almost all the nearly 300 carpools organized are comprised of faculty and employees (very few are student groups).

Reduction in travel time might be used to encourage carpools or bus ridership. Incentives of this type grant time saving to buses and/or carpools through a variety of techniques, including reserved lanes, priority entrances to freeways, reserved lanes at toll plazas, and bus priority traffic signal operation. Examples include:

- Shirley Highway. Buses and carpools of 4 or more persons are permitted to use an exclusive, separate roadway located in the median of the Shirley Highway in the Northern Virginia suburbs of Washington, D.C. Buses and carpools save approximately 15 minutes during the peak hour.

- Los Angeles. Automobiles with 2 or more persons are permitted to by-pass the queue at one metered freeway entrance ramp; carpool vehicles save 7 to 9 minutes during the peak hour.

- Oakland Bay Bridge: San Francisco. Reserved toll plaza lanes for buses and carpools with 3 or more persons save approximately 5 minutes during the peak hour. The number of carpools has nearly doubled following implementation of the reserved lanes.

Convenience measures to encourage carpools may be applied either positively to encourage carpools, or negatively to increase the inconvenience of not carpooling. Such techniques include preferential parking, space assignments for carpools, special park-ride lots for carpools, working hour adjustments, banning of low occupancy vehicles in selected areas, and limitations on parking spaces with permits issued only for high

occupancy vehicles. Examples of such application include:

- Texas State Department of Highways and Public Transportation, Austin. Preference in parking is given to vehicles having two or more employees riding together. There are 1,267 employees at the Camp Hubbard offices, and 492 numbered reserved spaces have been issued. Others may park in the remaining lot, which involves a walking distance of at least 600 feet.

- Little Rock, Arkansas. Provisions of 500 preferential close-in parking spaces resulted in the number of state employees in carpools increasing from 400 to 1,100.

Those programs which have an integrated approach composed of a combination of incentives and effective dissemination are likely to be the most successful. The degree of success depends largely upon the commitment and leadership of top management in pursuing an organized and adequately supported program.

An example is the Connecticut Department of Transportation in Hartford. In early 1972, the Connecticut DOT initiated a program involving carpooling among state employees working in the Capitol complex; this program included carpool matching, preferential parking, employee communication, and assistance to a private sector in organizing carpools. Individuals living in the same neighborhoods and working similar schedules were invited to informal coffee sessions held during work hours for the purpose of face-to-face contact in organizing carpools; group size ranged from 10 to 80 persons. Such an approach might be instrumental in overcoming various psychological barriers to the formation of carpools.

Parking spaces were numbered and assigned to qualified carpools consisting of four or more persons commuting together three or more days a week. At least three of the persons in a carpool must be state employees; the fourth or additional members can be nonstate employees. Security guards make periodic checks of the reserved spaces and unauthorized cars are subjected to a \$15 fine.

7.3 INNOVATIVE CARPOOL CONCEPTS

The emphasis on carpooling has been generally oriented toward individual firms. This necessarily limits the carpool market. Additionally, many alternative carpool systems are overlooked by this narrow view.

An innovative idea that can substantially increase carpooling has been suggested by CALTRANS. Companies and/or agencies can allow employees to use the company (agency) car for the work trip, provided he agrees to pick up four additional employees. Riders pay a small fee for the service which reduces the company's fixed cost.

Such an approach reduces parking demand as well as shares the cost of operating the company vehicle and eliminates the need for a second car on the part of the riders.

+ Matches Carpool - 954 -- 96.4% of Collected
 Transit - 610 -- 61.6% of Collected

7.31 Wilkes - Barre -- Luzerne County
Transportation Authority Program

● Program Elements

- + Area-wide newspaper, radio and television coverage
- + Major employers contacted and asked to voluntarily participate
- + Automatic enrollment through labor unions
- + Carpool forms screened and, where possible, matched to transit
- + No incentive programs were provided

● Area-wide Approach

1. Goals

- + Make public aware of project and how to participate
- + Make small employers aware of carpool potential
- + Reinforce idea to carpooler's in other program elements

2. Results

- + Only 24 calls received
- + 24 forms completed
- + Matches accomplished

Out of the potential of 80,000 persons, 17,740 were reached; thus, of a potential 62,260 persons, a .04% response was received and .01% matched.

● Major Employers - Contacted major employer requested-They distribute and collect carpool forms.

+Number of Employees - 16,215
 +Forms Distributed - 9,435 -- 58.2% of possible

 +Forms Collected - 990 -- 10.5% of distributed
 +Matches Carpool - 699 -- 70.6% of collected
 Transit - 620 -- 62.6% of collected

● Automatic Enrollment

Forms were completed by staff from the union records.

+ Number of Employees Covered 1525
 + Forms Distributed 990
 + Forms Collected 990
 100% of Distributed

● Conclusions:

1. Automatic enrollment far better than voluntary participation.
2. Pre-processing for transit match was very successful and is recommended to other agencies.
3. Of the matches some 80% did not use information provided. However, 33% felt that information was of value to them.
4. Only one-third of major employers participated on a voluntary basis.
5. Success ratio - 1 in 45 for major employers. 1 in 6 for automatic enrollment.

7.4 VANPOOL PROGRAMS

A vanpool substitutes one multiple, high-occupancy vehicle for several individual low-occupancy automobiles. The program might be organized and the vans owned by a company, apartment management, or other organized group to provide transportation for its employees or members. Vanpools operate like carpools except for the ownership of the vehicle and the larger number of persons in the pool. The van is commonly operated by a member of the pool whose regular employment is at, or in the same vicinity as the other pool members.

One of the first, and perhaps best known, vanpool programs was initiated by the 3M Company at its St. Paul facility. The 3M program utilizes company-owned vans with groups of 8 to 11 employees organized in each vanpool.

One member serves as the coordinator and principal driver and has the responsibility for servicing and maintaining the van, provision of a backup driver, collection of monthly fees and keeping the ridership at or above the minimum occupancy of 8. The pool coordinator/driver rides without charge and gets to keep all passenger revenues exceeding the minimum occupancy of 8 passengers. This provides an incentive to the coordinator/driver to maximize the number of persons in the vanpool, while providing a service which is satisfactory and tailored to the members of the vanpool.

Other companies which have organized vanpool programs include: General Foods, ARCO, and Continental Oil. Charges for service

generally range between \$15 and \$25 per month. Drivers usually pay no fee and retain fees collected from passengers over some minimum base, as in the 3M program.

7.5 INNOVATIVE VANPOOL CONCEPTS

Vanpools have been traditionally associated with individual firms or organizations. This has proven to be a very serious deficiency. Most employees live nearer the place of employment than can economically be served by vanpools.

The economics of vanpool operation are very similar to those of other transit modes. Approximately 75 percent of the cost of vanpool operations are fixed costs (i.e., not dependent on the mileage driven).

7.5.1 Vanpool Cost Elements

• Fixed Cost Elements

Vehicle Capital		
\$8,000 at 10% over 5 years	\$185/month	
Insurance	40/month	
TOTAL	\$225/month	

• Variable Cost Elements

Fuel (12 mpg and 60¢/gal)	5¢/mile
Maintenance	4¢/mile
TOTAL	9¢/mile

The length of the one-way trip length is dependent upon the price the user is willing to pay for the service. Using the cost figures presented above, the minimum trip length necessary to recover the cost of operation (No subsidy required) can be calculated.

• Assumptions

1. A 10-person vanpool with each person sharing equally the cost involved.
2. A fixed cost of \$225 per month and a variable cost of 9 cents per mile.
3. No cost of the highway or street system are included.
4. The driver/operator does not make a profit on the operation and shares equally in the costs.
5. There are 248 work days per year (5 x 52 - 12 Holidays).

$$\text{COST per person mile} = \frac{\text{Fixed Cost (\$/month)}}{(1/12) \text{ Work Days/year}}$$

$$\times \frac{1}{\text{Pool size}} \times \frac{1}{2(\text{One Way Trip Length})} + \text{Variable Costs}$$

$$\times \frac{1}{\text{Pool size}}$$

$$C_{\text{pass-mile}} = \frac{C_{\text{Fixed}}}{(1/12) \cdot 248 \cdot \frac{1}{10} \cdot 2L} + \frac{9¢}{10}$$

$$= \frac{1}{49.60} \frac{C_{\text{Fixed}}}{L} + 0.9$$

Rearranging the expression,

$$L = \frac{C_{\text{Fixed}}}{4.133 C_{\text{Pass-mile}} - 0.9}$$

Where:

L = one way trip length

C_{Fixed} = Fixed Cost of Vanpool Operation (dollars/month)

C_{Pass-mile} = price user is willing to pay per passenger mile in cents

Amount Each Rider Is Willing to Pay (¢/Pass-Mile)	Minimum One-Way Trip Length to Break Even (Miles)	Monthly Cost To Each Passenger For the Break Even Trip (Dollars)
C _{Pass-Mile}	(Miles)	(Dollars)
3¢	25.9	\$32
5¢	13.3	\$27
7¢	8.9	\$26
9¢	6.7	\$25
11¢	5.4	\$25

This computation suggests that for vanpools to be economically viable the one-way trip needs to be on the order of 25 miles for costs similar to the out-of-pocket costs of operating an automobile. Since the percentage of the employees of any single firm would live this far from work is relatively small, a very large employee pool is necessary to achieve even a single vanpool. Recent experience in California suggests that 3000 employees is about the minimum size firm that is necessary in a large metropolitan area to have any real chance of implementing breakeven vanpool operations at an income of 3 cents per passenger miles.

To alleviate this constraint, CALTRANS has proposed a program which would encourage an individual to purchase a van and operate a vanpool on a break even basis. A broad-based advertising program encourages anyone living 25 miles or more from work who would like to save money to contact state people who will assist them in obtaining the vehicle and advise on the necessary bookkeeping required. Also, names of potential riders are furnished from available listings.

The question of insurance and the required license as a common carrier are minimized since no profit is derived from the operation.

This innovative concept can increase substantially the potential for vanpooling.

7.6 SHARED RIDE TAXI

Taxi service is a form of demand responsive service which has traditionally catered to the individual passenger. Occasionally the taxi serves 2 or more persons traveling together. Shared ride taxi service differs in that 2 or more unacquainted individuals share the vehicle, similar to dial-a-bus systems. This holds the prospect of a more efficient use of the vehicle and driver and, hence, a lower cost per passenger carried.

The most publicized shared taxi operations exist in Davenport, Iowa, and Hicksville, New York. Both these systems are lease systems. The companies own the vehicles, pay the insurance, maintenance, licensing and dispatching; the driver pays for the gasoline. According to the information concerning the operations in Davenport and Hicksville, these systems are operating at a profit. Due to the fact that they are private operations, limited data are available to substantiate these claims. An estimate of daily operating characteristics in Davenport and Hicksville is presented in Table 7.1. These figures demonstrate 2 significant points. First, the shared ride cab companies are charging 2 to 4 times as much per ride in comparison to typical dial-a-bus operations. Secondly, the hourly earnings of the drivers are substantially less than the hourly rate paid bus drivers.

TABLE 7.1: SUMMARY OF DAVENPORT AND HICKSVILLE SHARED RIDE TAXI OPERATIONS

Daily Operating Characteristics	Davenport	Hicksville
Hours of Operation/ Vehicle	17.9	11.9
Average Miles/ Vehicle	208	170
Average Passenger Trips/ hour of operation	4.1	2.7
Passenger Trips/Day (average)	73	32
Average Revenue/Trip	\$1.05	\$2.15
Driver Revenue/Day (average)	\$76	\$68
Driver Cost/Day (average)	\$45	\$48
Driver Income (Revenue minus cost)	\$31	\$20
Average Hourly Driver Income	\$1.56	\$1.71

7.7 JITNEYS

The jitney is generally a small, privately owned transit vehicle operated on a fixed or semi-fixed route. Following their success in Los Angeles in 1914, jitney operations became widespread throughout United States cities. However, the franchised rail-transit operators were successful in a series of legal efforts which, by 1918, lead to most cities enacting ordinances which provided for strict control over jitneys. Jitney service has continued in only a few limited instances, some legally, but in most cases illegally.

Examples of cities currently having jitney operations are: San Francisco; Atlantic City; Ocean City, Maryland; Pittsburg; and Kansas City. Jitneys provide extensive service in any Central and South American cities: Puerto Rico, the Middle-East, and the Philippines. The jitney operation in Kansas City, Missouri, is provided as a demonstration project under the Kansas City Transit Authority.

Jitneys are suited to relatively low density travel transit patterns because of their small passenger capacity (up to 4 or 5 persons in a car, 8 to 10 persons in a van). Potential entrepreneurs for providing such service probably can be readily found in all cities.

Many of the problems associated with the unregulated jitney operators of the 1914-1918 time period should be relatively easy

to avoid; local governments have gained considerable experience in licensing and regulating since that time. Regulations and restrictions governing jitneys should be in regard to areas served (and not served) rather than in regard to routes so as to allow the jitney operator to tailor service to client desires.

Logical applications for jitney service are:

- The principal public transit service in cities presently without a bus service.
- A substitute service on marginal routes in cities with bus transit service.

7.8 SUBSCRIPTION BUS SERVICE

Subscription bus service is tailored to accommodate the needs of a specific, generally well defined, urban travel market. Individuals who use these services do so on a regular basis, principally for the work trip. Subscription bus service offers a number of benefits to the users as well as to the communities concerned; these include:

- Service is more responsive to the needs of the subscribers than conventional transit service.

- Cost may be less than travel by private automobile especially where parking costs are high.
- Riders may be able to reduce the number of autos owned.
- Reduced demand for parking.
- Homeowners, developers, and/or apartment investors may enjoy increased property values due to the availability of the service.
- Subscription service often can be operated with revenues equaling or exceeding expenses.
- A strong personal identity with the service may be developed which stimulates additional ridership.

Subscription bus service has generally involved special service features such as guaranteed seating, door-to-door service, express operation for most of the trip, routes and schedules that are designed in response to specific rider demands, and a degree of social interaction. Any group of trips that are made on a repetitive basis might be considered for subscription service; work trips, however, are the most promising market segment.

Experience indicates that premium fares can be charged for premium service and attract ridership.

7.81 Existing Services.

Costs and other related figures for selected subscription bus services are given in Table 7.2. Com-Bus is a private commuter bus operation serving over 3,000 Los Angeles area commuters each day. Routes are 18 to 65 miles one-way and serve 8 separate employment locations. Buses are obtained from different charter bus operators. Com-Bus coordinates routing and scheduling to give the rider maximum service in comfortable, air-conditioned coaches.

The Atlantic Richfield Company has also inaugurated a "Subscription Commuter" service in the Los Angeles area. Buses serve 6 routes that link major employee residential areas to the downtown Atlantic Richfield Plaza. Employees subscribe to the service at a charge of \$40 per month; the employer contributes a substantial amount to the monthly costs. Another Los Angeles area employer, the Aerospace Corporation has organized and sponsors nine buspools among its employees.

The Golden Gate Bridge Highway and Transportation District in the San Francisco area responded to requests to lease buses and drivers to "Commute Clubs." These clubs now operate 11 buses. The District sets the fares so that the club will become self-supporting when all seats are sold and

subsidizes it until then. The club solicits new members, collects dues, sets route and time schedules, and makes the monthly payment to the District.

The Reston service began with residents chartering one bus for the daily 20-mile commute into downtown Washington. By early 1974, the Reston Commuter Bus, Inc., consisted of 25 bus trips each way every working day including a Monday through Friday "straggler" bus which leaves Washington at 7 p.m. and an "early bird" bus which leaves Washington at 2:30 p.m. every Friday afternoon.

Also in the Washington D.C. area, the Columbia Association charters 22 buses (11 each way) to make the daily commute. Department of Health, Education and Welfare employees living in another Maryland suburb also charter a bus to take them directly to the Washington office.

Specialty Transit in the St. Louis metropolitan area is an independent operator which runs 24 buses each day from residential areas to the large suburban employment center occupied by the McDonnell Douglas Corporation. The bus drivers are also employees at the plant where special "close-in" parking spaces are reserved for the buses. Passenger fares range from \$4/week on the 9 mile route to \$7.50/week on the 52-mile route.

The provision for the riders to directly influence the design of the service is a key factor in all their buspooling programs. Decisions regarding route selections, scheduling, payment method, and amenities such as smoking regulations and refreshments are made by the users of the service. Under such conditions the service can be structured to cover costs.

7.82 Development of the Subscription Bus Market.

Most subscription bus operators have organized riders at the work end of the trip; in many cases the employer has taken an active role in matching riders, identifying routes, and establishing schedules. The Reston operation which was organized by individuals at the home end is a notable exception. In most instances the subscription operation will start with a limited number of passengers and one or two buses; as ridership is attracted, additional service is added.

Subscription bus service might be best suited to longer trips because traditional transit service is more likely to be unavailable or involves excessively long travel times and transfers as the length of the trip increases. However, there is limited evidence that properly designed and well managed operations might be successful in serving shorter trips (e.g., less than 10 miles).

TABLE 7.2 SUMMARY OF SERVICE PROVIDED BY SELECTED SUBSCRIPTION BUS OPERATIONS

Operation	Location	Organizer	Period of Operation	Number of Vehicles	Type Vehicle and Seating Capacity	Number of Subscribers	Length of Trip Served (miles)
City of Los Angeles	Los Angeles	employer	1974-	-	transit coach 50 passengers	-	-
Colonial Transit	Washington D.C.	private operator	1966-	16	-(42)	650-800	20-50
COM-BUS	Los Angeles	private operator	1967-	47	deluxe coach 45 passengers	1500-1700	20-65
Golden Gate	San Francisco	transit authority	1971-	11	deluxe coach 45 passengers	470	20-55
National Geographic	Washington D.C.	employer	1968-	8	deluxe coach 50 passengers	250	5-25
Reston Commuter	Reston VA	community group	1968-	25	transit coach 50 passengers	800-900	22
Specialty Transit	St. Louis	private operator	1958-	24	remodeled school bus - (41)	700-800	9-52
Wayward Bus	San Francisco	community group	1962-	2	deluxe coach 50 passengers	75-80	35-50
Maxicab	Flint, Michigan	demonstration model	1968-71	26	transit coach 45 passengers	300-330	1-8
Peoria Premium	Peoria, Illinois	demonstration model	1964-70	21	transit coach 40 passengers	500	5-14

Table 7.2 (Continued)

Operation	Location	Access		Seating		Income Level of Subscribers
		At Origin	At Destination	Guaranteed	Luxury	
City of Los Angeles	Los Angeles	walk/park-ride	to door	yes	some	medium
Colonial Transit	Washington D.C.	-	to door	yes	yes	low to medium
COM-BUS	Los Angeles	-	to door	yes	yes	medium
Golden Gate	San Francisco	walk, up to one block	to door	yes	yes	medium to high
National Geographic	Washington D.C.	walk, up to two blocks	to door	yes	yes	low
Reston Commuter	Reston VA	walk, up to one block	walk, up to two blocks	usually	some	high
Specialty Transit	St. Louis	park-ride	to door	yes	no	low
Wayward Bus	San Francisco	-	-	yes	-	medium to high
Maxicab	Flint, Michigan	door	to door	yes	no	low to medium
Peoria Premium	Peoria, Illinois	door	to door	yes	no	low to medium

Source: Kirby and Bhatt, "Operation of Subscription Bus Services" Report to Urban Mass Transportation Administration, 1974.

For example, the Peoria service attracted 43 percent of its ridership from automobile drivers and achieved load factors of over 0.6. Experience and analyses of mode choice characteristics suggest that more attention to the individual consumer is necessary in developing and maintaining the short trip markets.

Substantial effort is needed in organizing, as well as operating a successful subscription bus operation. Personnel directors of employers are generally in a good position and might be equipped to handle the responsibilities of an employer-organized service. In a transit authority, assignment of the responsibility to an individual or special marketing group is suggested. In any case, specific designation or responsibility within the transit operation for managing the service and effective communication with the user group are necessary. The most effective means of advertising is word-of-mouth by satisfied riders once service has been initiated.

Regulatory constraints will vary from state-to-state. Service that crosses state lines is subject to issuance of a certificate of "convenience and necessity," and regulation as to routes, schedules and fares by the Interstate Commerce Commission. Where the service is intrastate, approval of the state public service commission and/or local authority must be obtained. Arrangements for service through the existing transit system or transit authority may be a major ad-

vantage since most are able to provide contract services and to set routes, schedules, and fares for such contract service without additional approval by the regulatory body.

Conditions and characteristics necessary for the organization and continuation of a successful subscription bus service include:

- A concentration of common trip origins and destinations as well as common travel schedules sufficient for at least one bus.
- An effective group to organize the service.
- Continual attention to rider demands with appropriate adjustments in routes and schedules.
- Premium service such as guaranteed seating, express point-to-point service, and a high degree of schedule reliability.
- Convenient arrangement for service (e.g., an existing transit operation or charter bus operator).
- Attention to regulatory requirements.

Large organizations that are faced with inadequate parking, or environmental constraints, may find the formation of subscription bus service an economical substitute for employee parking. Others might be encouraged to consider it as an attractive fringe benefit for employees.

TABLE 7.3: SUMMARY OF COSTS FOR SELECTED SUBSCRIPTION BUS SERVICES

<u>Operation</u>	<u>Cost per Bus Trip</u>	<u>Cost per Seat-Mile</u>	<u>Load Factor</u>	<u>Cost per Passenger Trip</u>	<u>Cost per Passenger Mile</u>	<u>Approximate Fare, cents per Passenger-Mile</u>
City of Los Angeles	\$35-\$40	-	-	-	-	-
Colonial Transit	\$32	3¢	0.86	\$0.90	3.5¢	3.5¢
Com-Bus	\$40	2.2¢	0.73	\$1.20	3.0¢	3.0¢
Golden Gate	\$40	2.6¢	0.67	\$1.35	3.9¢	3.9¢
National Geographic	\$40	4¢	0.62	\$1.30	6.5¢	6.5¢
Reston	\$60	5.5¢	0.81	\$1.50	6.8¢	6.8¢
Specialty Transit	\$18.50	1¢	0.71	\$0.60	1.4¢	1.4¢
Wayward Bus	\$35	1.7¢	0.77	\$0.95	2.2¢	2.2¢

Source: Kirby and Bhatt, "Operation of Subscription Bus Services," Report to Urban Mass Transportation Administration, 1974.

7.9 INCREASING TRANSIT USE

Socioeconomic characteristics of the trip maker are major determinants in the choice between transit and private transportation. Since the income elasticity of transit use is negative (-0.9) and that of auto use is positive (1.2), increases in income among upward mobile, low-income households will result in decreased transit use by current "captive riders" (e.g., no car available). Conversely, a decrease in real income, as experienced beginning in late 1974, would result in increased transit use.

Among those who do own an automobile and have a choice between using it or public transit for a given trip, differences in travel time, accessibility costs, and other considerations affect the individual's choice. Specific conclusions can be drawn only after detailed market studies and initiation of service changes in specific situations. However, the experience of a variety of service and fare changes, together with demonstration projects, provide a basis for identifying the nature and direction of changes that will increase ridership.

The fact that transit ridership is fare inelastic indicates that fare reductions, in general, are unlikely to stimulate greatly increased ridership. Since transit demand is relatively more elastic to service than to fare, service improvements will have a greater effect on increasing transit ridership. In other words, for a given amount of subsidy, a larger number of passengers would use transit if fares were unchanged and service improved than if fares were reduced and service unchanged.

Furthermore, the relative elasticities of working time and in-transit time suggest that increased service levels (e.g., reduced headways) would be most effective in attracting increased ridership. Where frequent headways already exist (less than about 10 minutes) a fare reduction may have a greater effect on ridership than service improvements since further reductions in headway have less pronounced effect on waiting time.

Service improvements are likely to be more effective in higher income suburban areas. This would suggest increased use of higher fares for premium service in such areas.

7.91 Innovative Transit Fares.

The Municipality of Metropolitan Seattle (Metro) has taken a number of steps to increase transit usage in the Seattle area, including the initiation of an annual MetroPass which went on sale October 14, 1974. The MetroPass costs \$150 and allows the individual unlimited riding privileges for a period of one year at any time on a regular service route through three contig-

uous zones. This is expected to be attractive to suburban riders working in downtown Seattle. Metro is encouraging businesses to buy the pass as a fringe benefit, or permitting the employee to pay for the pass through payroll deductions or by monthly payments. A MetroPermit, which sells for \$4.00 per month, is also available and allows a customer to ride for ten cents (half the 20-cent base fare).

In cooperation with the city of Seattle, Metro has been providing a no-fare service in downtown Seattle since September 1973. For the 10-month period of September 1973 through August 1974, the city of Seattle paid Metro Transit \$64,000, in lieu of revenue of the same amount generated by the previous 10-cent shuttle. Since initiation of the no-fare downtown service, loadings on buses on downtown routes has doubled.

The City of Austin, Texas, has initiated monthly passes as an attempt to encourage increased use of the local bus system. A "Shoppers Pass" costs \$6 per month and is good for unlimited use between the hours of 9:00 a.m. and 3:00 p.m. and after 6:00 p.m.

7.10 POTENTIAL IMPACT OF RIDE SHARING PROGRAMS

It should be recognized that an aggressive program that is effective in increasing auto occupancy can be expected to detract from transit ridership. Those individuals who find carpooling and vanpooling acceptable substitutes for the traditional use of their private auto are those who might be most likely users of improved bus transit service. It is probable that intensive efforts in organizing a large number of vanpools, will present some current transit riders with a home-to-work travel option which will provide a superior level of service at a similar or lesser cost. Carpool programs will have a similar effect, but perhaps to a lesser extent - particularly when members of the carpool must take turns driving. However, there are numerous situations where the number of trips between given origins and destinations within the same time schedule is considerably short of that necessary to provide an economical transit service. In these instances, vanpools and carpools offer the most cost-effective and energy-efficient means of making the trips.

Similarly, the tailored service provided by subscription bus operation may also detract from conventional bus transit ridership. However, there are undoubtedly numerous markets involving longer distance home-to-work trips that are not presently served by any form of transit which subscription service might effectively tap.

This potential for simultaneous programs paralleling conventional bus transit and

carpools or vanpools to be counter-productive should be recognized at the outset. Attention can then be directed toward developing concurrent vanpool/carpool and conventional bus transit programs that will be the most cost-effective for the service area.

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CHAPTER 8

IMPROVING PUBLIC TRANSPORTATION

SESSION OBJECTIVES:

1. *To review the principal methods of implementing bus rapid transit and to identify major problems associated with each.*
2. *To review methods for improving urban transportation through preferential treatment of buses and other high occupancy vehicles.*
3. *To identify potential public transportation service improvements.*
4. *To discuss various management and policy aspects of implementing transit improvements.*

8.1 INTRODUCTION

The public sector of urban transportation involves two substantially different problems with respect to movement requirements - provision of base level mobility and mass transit. Basic mobility is the provision of some specified level of mobility for those who are not able to provide their own private transportation. This in itself involves a number of different needs, problems, and service markets such as the economically disadvantaged, handicapped, those who cannot drive, etc. Travel demand is for a small number of trips between a diverse number of locations. Mass transit, on the other hand, involves the movement of large numbers of people between a relatively small number of given locations. Base level mobility is a response to a social need. The nature of the low density travel patterns involved results in relatively high unit costs while the ability of the public transportation user to pay is relatively limited. Therefore, revenues will not be sufficient to offset expenses and some amount of subsidy will be required; the higher the level of service provided, the larger the amount of the total subsidy required.

Mass transportation costs, in the long run, can be covered largely from fares. However, if sufficient revenues are to be generated to offset expenses, major public issues must be resolved so as to reach cost-effective decisions. The principal issue is the relationships between demand and use activity patterns and urban transportation addressed in Session 4.

This session will review available forms of

urban public transportation and explore opportunities by which each might be improved or applied cost-effectively.

8.2 BUS TRANSIT IMPROVEMENTS

The 1970 Census showed 247 metropolitan areas in the United States. The majority (some 222) are less than 1 million in population; bus system improvements offer the possibility of providing cost effective public and mass transportation in these cities. Even in the nation's 8 metropolitan areas which have or are committed to fixed rail systems, bus transit will continue to carry a significant portion of the total transit riders. In the other 17 urbanized areas of over 1-million population, bus transit presents the possibility for implementation of rapid transit service within the decade of the 1980's and perhaps in most cases in the 1990's.

8.21 Local Bus Transit.

Buses currently carry about three-fourths of the total U.S. transit passengers. Buses usually achieve average schedule speeds of 10 to 12 miles per hour (including stops) in peak periods and about 14 miles per hour in off-peak periods. In highly congested urban areas such as Paris and Tokyo, average speeds are as low as 6 to 8 miles per hour. When operating closed-door over arterial streets, speeds of about 25 miles per hour are attained.

Headways between buses might be as short as a few minutes during peak-hours but lengthen to 30 minutes or an hour during midday. When ridership was much greater, transit routes were commonly spaced at one-mile intervals or less. However, as ridership declined, both route spacing and headways were increased.

Traditionally, buses have picked up passengers at any street corner along the route. Commonly, shelters or other amenities, are very limited or infrequently provided.

In most developed corridors in existing urban areas, the potential transit demand is small and bus rapid transit offers a means of providing a high level of service at much lower cost per passenger than the more capital intensive fixed-way modes. Some of the advantages of bus transit include:

- Buses can operate over the existing street and freeway system. Therefore, bus systems can be implemented, and major service expan-

sions made in a relatively short period of time.

- Buses can be used to provide charter or other service when not needed in scheduled service.
- A relatively small number of passengers is needed in order to justify dispatching a bus; therefore, buses can service more diverse, low density transit travel patterns than fixed-way systems.
- The undepreciated investment is largely salvageable if service should be terminated.

8.22 Bus Rapid Transit - Definition and Options. As the term implies, Bus Rapid Transit (BRT) is the provision of a rapid transit service, analogous to the RRT service, utilizing buses as the rolling stock. The mode of operation might be:

(1) Line-haul vehicles operating through stations to which passengers arrive by feeder bus, park-ride, taxi, or by walking.

(2) The same bus that provides the collection/distribution also performs the line-haul portion of the trip.

The fixed-way for the operation of bus rapid transit might be provided in the following ways:

- Exclusive busway
- Reserved freeway lane
 - + Contraflow
 - + Normal flow
- Metered freeway

8.22.1 Exclusive Busway. The provision of special grade-separated roadways for the exclusive use of buses would allow BRT vehicles to operate without interference of other traffic. However, the construction of such busways involves substantial expense; this limits the cost-effectiveness of the concept unless transit ridership is exceptionally high. The largest volume of bus passengers on the exclusive lane is carried on the approaches to the Lincoln Tunnel, where 33,000 persons are carried in 770 buses between 7:30 and 8:30 a.m. There are few other corridors in which there is a demand for as many as 100 buses. A single lane can accommodate these 100 buses plus some 1,000 automobiles and still yield a service level of about 50 miles per hour. This suggests that the cost-effectiveness of a busway can be improved substantially by allowing high-occupancy autos to use the facility. Such operation should encourage the formation and use of carpools.

8.22.2 Reserved Freeway Lane. Under this concept, one lane of a freeway is designated for use by the BRT vehicles. Since the number of buses per hour in existing urban freeway corridors (except for the I-494 approach to the Lincoln Tunnel in the New York City Metropolitan area) cannot effectively utilize the capacity on one lane, high occupancy automobiles can also be permitted to use the reserved lane, or lanes. Buses and high occupancy vehicles might also be given preferential entry to the freeway via "exclusive" ramps or allowing them to by-pass the queue of an existing ramp.

This technique might be quickly implemented since operational changes are involved. However, there are a variety of important considerations which must be properly dealt with; these include the following:

- The concept of a reserved lane, or lanes, is potentially feasible on six, eight, or ten-lane freeways. It is not feasible where a single unreserved lane would remain for the use of other traffic.
- The inside (median) lane is the logical choice for designation as the reserved lane. Use of the outside lane as the reserved lane would require that all nonpreferential vehicles would have to weave through the reserved lane on entering and leaving the freeway. Since there is no specific, identifiable distance for which it would be reasonable for nonpreferential vehicles to occupy an outside reserved lane, it is highly questionable if adequate enforcement could be achieved.
- Designation of the inside lane as the reserved lane, of course, means that the preferential traffic (buses and carpools) would have to weave through the nonreserved lanes. Obviously, severe congestion in the nonreserved lanes would block entry and exit to and from the reserved lane(s). Construction of exclusive left-hand ramps would be an expensive solution.
- Traffic lanes, vehicles, and occupants exist only in discrete units. This gives rise to discontinuities in the flow regimes, as indicated in Figure 8.1. For example; consider a 4-lane roadway (8-lane freeway) with an average auto occupancy of 1.4 persons per vehicle and 2 lanes reserved for buses and high occupancy autos. The 2 unreserved lanes would be "jammed" under all auto occupancy conditions.

Therefore, it appears that the conditions at each specific location should be carefully analyzed prior to attempting to implement a reserved freeway lane for carpools.

- Enforcement of lane use must be exercised over a continuous and substantial length of freeway.

MEDIUM OCCUPANCY-INITIAL MEAN=1.40

RESERVED LANE RULE		NUMBER OF FREEWAY LANES				
		3		4		5
		NUMBER OF RESERVED LANES				
		1	1	2	1	2
NO. OF OCCUPANTS	2 OR MORE		R	U	R	
	3 OR MORE	U		U		U
	4 OR MORE	U	/	U	/	U

LOW OCCUPANCY-INITIAL MEAN=1.176

RESERVED LANE RULE		NUMBER OF FREEWAY LANES				
		3		4		5
		NUMBER OF RESERVED LANES				
		1	1	2	1	2
NO. OF OCCUPANTS	2 OR MORE			U	/	/
	3 OR MORE	U		U		U
	4 OR MORE	U	U	U	/	U

- GOOD POTENTIAL
- LIMITED POTENTIAL (LITTLE SPEED ADVANTAGE)
- LITTLE POTENTIAL (LARGE SHIFT REQUIRED)
- NO POTENTIAL (RESERVED LANE JAMMED)
- NO POTENTIAL (UNRESERVED LANE JAMMED)

Figure 8.1 General Feasibility of Reserved Lane Concept

Source: Cappelle, Wagner, and Hensing, Feasibility and Evaluation Study of Reserved Freeway Lanes for Buses and Carpools.

8.22.3 Metered Freeway. Under the metered freeway concept, buses are given priority entry to the freeway. If desired, high occupancy autos also can be provided preferential entry. Other traffic entering the freeway is metered so as to provide the desired level of service (speed). Enforcement is needed only at a few specifically identified exclusive on-ramps which are to be used only by buses and high occupancy autos. If necessary, gates (similar to those used at restricted parking lot entrances/exits) could be installed. Such gates could be activated to allow passage of buses, without stopping, through manual activation from the control center or automatically by means of a bus detector or by an on-board device. Carpool drivers could be issued a coded "pass card" which would be inserted into a reading device located on the ramp to activate the gate. Closed circuit TV could be utilized to facilitate enforcement.

Experience has shown that traffic flow is significantly improved with freeway control. As a result, travel time through the system is reduced while average speed and capacity are increased.

In most instances, 30 to 100 buses in the peak hour will more than accommodate existing potential transit patronage. Hence, initiation of a bus rapid transit operation at the outset of freeway surveillance and control can be expected to meet potential patronage demand and still accommodate the existing vehicular traffic volumes.

Capital costs of converting an existing freeway to bus-freeway operations are estimated at about \$95,000 to \$125,000 per mile for such elements as detectors, signals, TV surveillance, hard wire telemetry, and provision of preferential bus ramps. Per-mile costs, of course, vary with the design of the freeway (especially the number of ramps which need to be controlled), the length of freeway segment to be controlled, and the design of the surveillance/control system.

Representative costs that might be used in developing preliminary estimates for metered freeway - BRT are given in Table 8.1.

8.3 EXAMPLES OF PREFERENTIAL TREATMENT

More efficient utilization of urban freeways and arterial streets can be achieved through preferential treatment of high occupancy vehicles - both transit and private. In comparison with the alternatives of construction of additional capacity for motor vehicles or fixed guideway systems, implementation can be accomplished both quickly and inexpensively.

8.31 Separate Roadways For Buses and Carpools.

A 2-lane busway was constructed on an 11-mile segment of the San Bernadino Freeway between El Monte and the Los Angeles CBD. Cost, including 100 new buses was \$60-million. Bus patronage increased from 1800 daily riders in 1973 to some 15,000 in 1976; 92% are for work. Implementation of the busway did not result in a decrease in peak hour auto traffic. Transit vehicles enjoy a 10-minute or more saving in travel time.

The busway located in the median of the Shirley Highway in the Northern Virginia suburbs of Washington, D.C., has 2 reversible lanes. This 11-mile busway was implemented in stages with completion in 1971. Vehicles using the preferential lanes achieve a time saving of 10 to 15 minutes over other traffic. Daily transit ridership has reached 25,000 passengers in each direction carried in over 350 buses; this represents a 6-fold increase since the preferential lanes were opened. In December 1973, use of the preferential lanes was extended to autos with 4 or

TABLE 8.1. Functional Unit Costs For Metered Freeway-BRT System
(1971-72 Dollars)

SEGMENT	CONTROL SYSTEM		OTHER FIXED FACILITIES	
	Elements	Cost per Segment	Elements	Cost per Segment
per ramp	detectors signals	\$ 17,200		
plus per mile	telemetry	46,900	park and ride lots shelters bus ramps	\$ 48,000
plus per system	computer telemetry equipment display equipment service equipment	860,000	control center building office furniture	600,000
<p>The estimated cost of a 30-mile system having 32 on-ramps would be estimated at:</p> <p style="padding-left: 40px;">Total Estimated Cost = (32 ramps) (\$17,200/ramp) + (30 miles) (\$46,900/mile, control + \$48,000/mile, other facilities) + (\$860,000/system, control + \$600,000/system, other facilities) = \$448,000 + 2,847,000 + 1,460,000 = \$4,775,000 for a 30 mile system exclusive of buses</p>				

more occupants without adverse effect on the buses. The number of carpools using the facility each morning increased from 200 to 1,000 in the first year.

8.32 Reserved Contra-flow Lanes. Preferential treatment might be afforded to buses by providing contra-flow operation on urban freeways where imbalance in traffic in the direction of minor flow during each peak period. Removal of the buses from the regular traffic lanes also enhances traffic flow - especially where up-hill grades are encountered. Experience with contra-flow operations indicate that time savings of about 1.0 to 4.0 minutes per mile might be achieved. The maximum saving is on the Long Island Expressway where the time saving to the buses is 7.5 minutes per mile over other traffic. Capital costs seem to be in the range of \$50,000 per mile with annual operating costs of \$14,000 to over \$50,000 per mile.

Buses using the 2.5-mile section of I-495 save between 10 and 15 minutes. The 40,000 passengers on 950 buses each 2-hour peak period (57,000 total daily passengers each direction) represent the highest bus passenger volume observed anywhere.

Contra-flow operation on the Long Island Expressway in New York City was initiated in October 1971; start-up cost was \$100,000, and operating costs are \$500 per day. The 10,000 peak period passengers in 200 buses save up to 15 minutes over the 2-mile segment.

In order to improve the evening peak period flow, contra-flow operation was initiated on 5 miles of U.S. 101 north of the Golden Gate Bridge. An 80-20 split enables the use of one of the 4 lanes in the direction of minor flow to be used as a buffer between the contra-flow bus lane and normal traffic. Time savings range from 8 to 20 minutes.

8.33 Reserved Normal Flow Lanes. Experience with normal flow reserved freeway lanes (diamond lanes) has been gained through various preferential application across the country. Where additional capacity was not provided prior to implementation of the diamond lane, such as the Santa Monica Freeway in Los Angeles, substantial adverse reaction has resulted. Costs have ranged from \$11,000 to over \$2-million per mile for construction; no operating cost data are available. An expected time saving appears to be about 1.0 minute per mile.

A reserved lane was implemented in a 2-mile section of I-280 in San Francisco in October 1975; operation is from 4:40 to 5:40 p.m. The reserved lanes save 2 to 3 minutes over the non-reserved lanes on which travel time is about one minute longer than before implementation of the reserved lane operation. In view of the low volume, 14 buses and 189 carpools (3 or more persons), it is perhaps not surprising that violators were 80% without enforcement. Diligent enforcement reduced violations to 16% of the traffic in the reserved lane.

The reserved lane on the Manualua Freeway experienced a 10% violation rate with "normal" enforcement. The reserved lane is in operation 24 hours a day and carries some 1,300 carpools (3 or more persons) and 11 buses in the peak period. The freeway was reconstructed to provide additional lanes; these lanes were converted to "diamond lane" operations prior to opening. The additional cost for this conversion was \$36,500.

The diamond lane was opened on 12.5 miles of the Santa Monica Freeway on March 15, 1976; metering was also implemented on the on-ramps. Travel time for traffic using the freeway was not charged while vehicles in the diamond lane achieved a 0.4 minute per mile saving. Substantial negative reaction resulted, and the reserved lane operation was terminated (additional environmental impact studies were also ordered) under court order on August 9, 1976; the ramp metering was not covered by the court order and continued in operation.

During the 21 weeks of operation the number of carpools increased by 2.5 times, and transit ridership tripled. During the 21st week, the diamond lane carried 16.9% of the persons using the freeway in the peak period as compared to 6.3% before the lane was opened.

The Banfield Freeway (Portland, Oregon) was reconstructed from 4 to 6 lanes with the added lane in each direction designated as reserved for buses and carpools in the morning and evening peak periods. Although there was an extensive pre-implementation information effort, some negative reaction to the diamond lane was voiced. This and the 30% violation rate may be due to the relatively low utilization - 23 buses plus some 120 carpools (3 or more persons) in the a.m. peak hour and 32 buses plus about 200 carpools in the p.m. peak hour. The reserved lane resulted in a 0.8 minute per mile savings to vehicles using it, and carpools have increased from 3% to 5% of the total traffic using the freeway in the peak hour.

3.34 Example of the Metered Freeway BRT Concept. Implementation of preferential bus service on I-35W in Minneapolis represents the first BRT operation utilizing the bus-freeway concept. Total cost of the 14-mile system, based on the accepted construction

bids, is \$2,197,800; a summary, indicating the major elements of the system, is given in Table 8.2.

Ridership at the maximum load point is currently 3,500 passengers per day in each direction more than a 3-fold increase. Service on the 16 routes which presently operate over I-35W is provided by 75 buses in the 6:00 to 9:00 a.m. period, and by 76 buses in the 4:00 to 6:00 p.m. period.

Table 8.2. Summary of Cost for the Traffic Management System Implemented on I-35W, Minneapolis

Detectors and Ramp Control	\$922,700
Closed Circuit TV	\$303,500
Computer Subsystem	\$308,900
Telemetry Equipment	\$234,000
Monitor and Display Equipment	\$ 52,800
Service Equipment	\$ 86,000
Control Center	\$277,000

Source: Minnesota Highway Department

General traffic benefits resulting from the implementation of the metered freeway-BRT operation on I-35W is evidenced by the change in traffic conditions during the one-hour period of heaviest traffic (6:50 to 7:50).

Before and after data for three bottleneck locations are given in Table 8.3.

Peak hour traffic volumes through these bottleneck locations were increased by some 20 percent, while speeds were simultaneously increased some five to ten miles per hour. Traffic volumes of 2,000 vehicles per hour per lane for the one-hour period, 6:50 to 7:50 a.m., have been obtained at all three locations.

However, the most dramatic improvement has been on that segment of the system from Minnesota Trunk Highway 13 to the Minnesota River. Prior to control, traffic volumes never exceeded 3,400 vehicles per hour; after control, the peak hour volume has never been below 3,500. Travel time over the two-mile segment was reduced from some 6.7 minutes to about 4.7 minutes. While part of this 2-minute saving for autos is consumed by additional waiting time at the on-ramps, it represents a significant improvement in the level of transit service.

TABLE 8.3. Traffic Conditions at Bottleneck Locations on I-35
Before and After Implementation of Bus Rapid Transit

Location	Number of Traffic Lanes	BEFORE		WITH BRT OPERATION	
		Average Volume	Average Speed	Average Volume	Average Speed
Minnehaha Creek	3	4400-5500	25 mph	5700-5900	30-35 mph
East Junction of I-35W and Crosstown Freeway	2	2800-3300	20 mph	3700-3800	30-35 mph
Minnesota River	2	2800-3400		3600-3800	

8.35 Priority Access. Preferential entry/exit on freeways and at toll plazas can also be provided for buses and high occupancy autos. In Seattle, buses operate in mixed traffic using the reversible lanes on I-5. Buses use an exclusive exit ramp which feeds into a special circulation loop in the downtown area. In the evening the operation is reversed and the ramp provides exclusive entry for the buses. Some 10,000 daily passengers ride the buses using this exclusive ramp. Similar preferential operations might be considered where closely spaced ramps already exist, or where they can be inexpensively provided.

In Los Angeles several by-pass lanes are provided by buses at metered freeway on-ramps; 2 such by-pass lanes to I-405 were implemented for carpools. These experimental by-passes for carpools utilize the shoulder by restriping and signing. Autos with 2 or more occupants may use these lanes; savings of 7 to 9 minutes are achieved over the single occupant vehicles at the metered entrances. At one location, the by-pass lane carried 460 carpools in the afternoon peak (a 268 percent increase). The number of carpools using another ramp location each morning increased by 156 percent (to 354) in the first month of operation. Plans call for implementation of metering on 2,000 ramps in the Los Angeles area.

In the San Francisco area, 3 of the 17 lanes on the Oakland Bay Bridge have been reserved for buses and cars with 5 or more occupants. Buses use one of the lanes without stopping (the transit company is billed directly). Monthly passes are available to carpools at reduced rates. This pass is displayed on the windshield and permits the carpool "nonstop" passage through the toll gate. Over 20,000 passengers on 520 buses and 1,800 carpools save a minimum of 5 minutes each morning.

8.4 PREFERENTIAL TREATMENT ON CITY STREETS

The capacity of one lane of an arterial street, using curb-side stops, is well over 100 buses per hour. This number of buses is more than sufficient to accommodate potential transit travel demands in all but the most densely traveled corridors in the nation's largest cities. This suggests that thorough consideration and significant effort should be directed toward improvement of the transit service provided over the city street system.

The following various possible types of improvements are listed in their approximate order of effectiveness in providing increased level of service. It should be noted that the values presented for bus lanes, median bus lanes, and bus only streets are based on judgment and specific applications. Therefore, they should be interpreted as indicative only; a specific potential application should be evaluated given the particular local circumstances. It should be further noted that neither FHWA or UMTA have warrants for bus lane applications at this time.

8.41 Preference in Signing. At intersections which have a 2-way stop, the stop signs might be positioned on the intersecting street instead of the street over which the bus is routed.

8.42 Preference at Traffic Signals. When a bus approaches a signalized intersection, the green phase can be either extended or advanced so as to allow the bus to clear the intersection without stopping for the signal.

8.43 Normal-flow Curb Bus Lane. Curb lanes for buses operating in the direction of normal traffic flow are relatively easy and inexpensive to implement. In areas where the volume

of buses is sufficient to utilize a major portion of the capacity of the curb lane, the operation will be somewhat self-enforcing. However, when the lane carries a small number of buses per hour, private vehicles will attempt to use the lane, and enforcement problems result.

- General Applicability. 1,200 to 1,600 passengers or more per hour, one-way desirable; two other lanes of traffic in same direction
- Capacity. 120 buses per hour
- Typical Capital Costs. \$3,000 to \$6,000 per mile
- Potential Benefit. time saving 1.5 to 5 minutes per mile in travel time

8.44 Contra-flow Curb Bus Lane. Operation of buses in the opposite direction to normal traffic flow on a one-way street enables the buses to utilize unused capacity where there is an imbalance in peak period traffic. Such bus lanes are largely self-enforcing and provide higher operating speeds than normal-flow curb lanes.

- General Applicability. 1,600 to 2,400 or more passengers per hour one-way desirable; at least two other traffic lanes.
- Capacity. 120 buses per hour
- Typical Capital Costs. \$4,000 to \$100,000 per mile.
- Potential Benefit. time saving of 1.5 to 6.5 minutes per mile.

8.45 Median Bus Lane. Bus lanes can be provided in the median of wide, multi-lane divided streets (e.g., Canal Street in New Orleans). Separation of the buses from other vehicular traffic along the same arterial eliminates this source of traffic friction and increases transit speeds. Bus preemption of signals (or progression for expediting transit if the number of buses warrant) can further increase transit speeds by reducing delay due to cross traffic at intersecting streets. At bus stops, islands separating the median bus lane from the adjacent traffic lanes must be wide enough for passenger safety.

- General Applicability. 2,400 to 3,600 or more passengers per hour one-way desirable
- Capacity. 120 buses per hour per lane
- Typical Capital Costs. \$15,000 to \$100,000 per mile
- Potential Benefit. 1.5 to 6.5 minutes per mile saving to buses

8.46 Bus Only Streets. Streets for buses only provide the most effective means of separating transit vehicles from other vehicular traffic and are easily enforced. When designed as part of an overall improvement of an existing street, other elements such as widening of sidewalks can provide for increased pedestrian capacity and other amenities (e.g., Nicolett Mall, Minneapolis).

- General Applicability. 3,600 or more passengers per hour one-way; ability to serve adjacent buildings in off-peak (at night) or from alleys and other streets.
- Capacity. 120 buses per hour per lane
- Typical Capital Costs. \$500,000 to \$2 million per mile
- Potential Benefit. 1.5 to 8 minutes per mile saving to buses

8.5 OTHER STREET IMPROVEMENTS

Various other street improvements can be made which will enhance the quality and level of transit service. Some can be provided at modest cost; others require that consideration be given to buses in design and reconstruction. These include the following:

8.51 Pavement Surface Condition and Drainage Features. Irregular pavement surfaces which feel comfortable to the passenger and occupant provide noticeable rough rides on modern, well maintained transit buses. The quality of the pavement necessary for a smooth bus ride is higher than that needed for a comfortable auto ride.

Depressed curb lines extending through the intersection to facilitate surface drainage necessitates that a bus decrease speed (more than an automobile) when traveling on the street perpendicular to such a drainage line. This causes a noticeable effect on the quality of the transit service by virtue of the appreciable reduction in speed and an uncomfortable "jolt" as the front the rear axle crosses the extended gutter section.

Also, drainage inlets commonly are located and designed so as to cause a noticeable and uncomfortable vertical and horizontal motion. Offsetting the inlet behind the curb line so as to eliminate the "dip" in the outside wheel path will eliminate this problem.

8.52 Increased Curb Return Radii. Curb return radii (5 to 15 feet) commonly employed are grossly inadequate for city transit coaches. Radii on bus routes should be increased so as to allow a bus to make a right turn without the need to encroach upon the on-coming traffic lane(s) and/or for the right rear wheels to "jump" the curb.

8.6 IMPROVING BUS SERVICE IN DOWNTOWN AREAS

Improvements to transit service must be continued into the downtown if the maximum total benefit is to be gained from priority treatment and other improvements on the line-haul portion of the trip. Downtown improvements which have been implemented in different cities to improve traffic flow and bus service include:

- Prohibition of parking
- Restriction of curb lanes for use of buses and right turning vehicles
- Designation of bus only lanes, either the curb lane or in the street median
- One-way streets
- Improved intersection channelization
- Preference at signalized intersections
- Incorporation of a busway within a mall or auto free zone.

In many cases, bus lanes operating in the normal direction of traffic flow are shared with right turning vehicles and/or taxis. Travel time for buses might be reduced by 5 to 40 percent, with savings averaging about 25 percent; traffic speeds in the adjacent lanes increased about 10 percent. Buses sharing the curb lane with right turning traffic gained an 87 percent increase in speed during the afternoon peak while traffic speed in the other lanes increased 22 percent.

Exclusive lanes for buses have been developed on the downtown portion of Canal Street in New Orleans. Contra-flow lanes have been implemented in San Antonio, Chicago, Louisville, Harrisburg, San Juan, Seattle, and Kansas City.

In areas having high bus volumes, entire blocks might be converted to the exclusive use of buses such as on a one block section of streets in Washington, D.C. This solves many of the problems involved where several routes and the use of adequate bus stop signs will further facilitate bus movement and passenger convenience.

An exclusive bus street was incorporated into the design of Nicollet Mall in Minneapolis. Chicago has also implemented an exclusive bus street. In Portland, some 77,000 passengers are carried on 7th Avenue which is restricted to bus only use; however, temporary access is provided to some adjacent properties while alternatives are being implemented.

Further improvement in bus movement through downtown areas might be achieved through traffic control measures. Such techniques might include: permitting buses to make left turns at restricted intersections during

peak periods, signal preemption by extending or advancing the green phase at individual intersections, or area-wide traffic control. The computerized system controlling 111 intersections in downtown Washington, D.C., incorporates a bus priority control strategy. Some 500 buses have been equipped with special transmitters which activate detectors at selected intersections.

8.7 OTHER TRANSIT-RELATED IMPROVEMENTS

If transit is to be made more competitive in attracting the urban trip maker, his portal-to-portal needs must be satisfied, and the service must be convenient and dependable. Transit service can be enhanced by a variety of amenities and support features.

8.71 Park-Ride and Terminal Facilities. Fringe and remote parking provides a means of collecting patrons at points so that reasonable load factors and, hence, costs per passenger can be achieved. Park-ride lots are especially appropriate where commuters and other trip makers from low density residential areas have desires for travel to high density focal points such as a central business district or concentrated employment centers. In such situations, a bus has a very low productivity rate (passengers per mile) and is hence uneconomical for collection/distribution at the residential end of the trip. On the other hand, a bus with a high load factor makes much more effective use of the limited capacity in the densely developed area.

Parking frequently can be obtained in church and shopping center parking lots. Use of such existing parking is especially advantageous for immediate implementation programs. Large shopping centers typically have unused space at the fringe of their parking areas - except perhaps during the Christmas shopping period. However, peak demand during this holiday period is characteristically in the evenings and on weekends which do not conflict with use by weekday commuters. In return for use of the parking spaces, the shopping center receives publicity and additional business. In Milwaukee, the shopping center names are used as route designations. In northern climates, there may be an additional advantage in snow removal. In Minneapolis, for example, the Minnesota Department of Highways plows the access to the park-ride areas. Following an overnight snow fall, the highway department snow plows are out before the commuter trips begin and well before the shopping center management would begin clearing snow. Therefore, access is clear for early arriving employees and shoppers.

Park-ride lots should be easy to find and be located so that the bus need travel only a very short distance off the route to serve it. Trail blazer signs should feed the first-

time user to the park-ride lot conveniently and without confusion. Where the parking for transit patrons is within a large parking area, such as at a shopping center, signing should clearly indicate the specific location of the spaces devoted to the park-ride operation.

Where the volume of passengers is sufficient, off-street bus terminals eliminate the pedestrian-vehicle conflicts and restrictions to traffic flow associated with curbside loading and unloading. Properly designed terminal buildings provide a safe, comfortable environment for waiting passengers where they are protected from rain, wind, and extreme temperatures. They also eliminate the sidewalk congestion involved where large numbers of passengers board.

8.72 Marketing and Customer Services. Other customer services and amenities which can be utilized to attract ridership to public transportation include marketing programs, convenient schedule information, and shelters. Provision of route and schedule information which is readily available to riders and potential riders is an important aspect of promoting transit use. Aggressive marketing programs might be effectively employed to extend the exposure of this information beyond the current ridership. For example, Dallas Transit System (DTS), in cooperation with downtown restaurant operators, used the theme "take a free bus to a free lunch." The idea was that the "free sample" would expose a number of nonriders to DTS and that some of these individuals would subsequently choose to use the bus service. The restaurants participating in the program also hoped to attract new clientele through the program.

Route and schedule information must be easily understood and readily available if potential riders are to be encouraged to use the transit service.

Distribution of pocket-size route maps and schedule cards, erection of route markers and bus stop location signs, provision of route maps at bus stops which display the route and schedule information relative to that specific location are approaches which have been employed. Chicago, Los Angeles, Boston, and Erie, Pennsylvania, are cities where new bus service information signs which display schematic route maps, stops, fares, times, and other information have recently been provided at bus stops.

Provision of route and schedule information in Braille will assist blind passengers in using the system. Golden Gate Transit provides route information in Braille on bus stop signs while Topeka and Wichita, Kansas, as well as Philadelphia, have schedules available in Braille.

A customer information/service center which riders may call for route and schedule information can be helpful in attracting riders who are not familiar with the system. Advice as to where and when to catch the bus and where to get off can be especially helpful to the occasional rider.

Dependability has been found to be an important attribute of transit service. Automatic vehicle location and monitoring systems can be employed to monitor vehicle schedules; Chicago has implemented such a system and one is being planned for Atlanta. Integration of a vehicle monitoring system into a passenger information system could provide waiting passengers with current information as to route, arrival time, etc., at major stops. Automated announcement boards with changeable messages are planned for the 69th Street terminal in Philadelphia to provide passengers through this busy terminal facility with information which will alleviate the confusing conditions and make more orderly boarding possible. On-board visual and/or audio messages might also be used on buses to advise passengers of the next stop. Such messages may be similar to those currently used on the BART system in San Francisco and on AIRTRANS at the Dallas-Fort Worth Airport.

Properly designed and adequately maintained bus shelters can improve the quality of the transit service by making the waiting period more pleasant - especially on cold or rainy days.

Fare structures and collection procedures can also be used to yield improvements in transit service. In addition to the security advantages, the use of exact fares and tokens speed passenger boarding and shorten delays at bus stops. Prepaid fares have a similar advantage; they also provide opportunities for convenient payment through payroll deduction plans, such as in Pittsburgh and the John Hancock National Life Insurance Company in Boston. Collection of fares prior to entering the transit vehicle (as is common practice on rail systems) frees the driver of the fare collection task and further speeds the boarding process. Such practice is feasible at park-ride lots and where a single system-wide fare is in effect.

8.73 Taxi Service. Taxis constitute the only form of public transportation in many urban areas. Nationwide, there are approximately 7,200 select operators plus thousands of individual owner-operators providing service in some 3,300 communities. Most cities over 100,000 (95 percent) require the use of meters to compute fares. Of the smaller urban areas, 65 percent require the use of meters, 24 percent have zone rates, and 9 percent have flat rates; the remaining 2 percent do not regulate fares.

While transit has been a heavily subsidized, public-dominated industry, taxicab operations have remained a highly competitive, privately-owned and operated industry. Very few taxicab companies receive any form of subsidy or financial assistance from any level of government; little concern or attention has been devoted to the problems or nature of the taxicab business. As suggested by the information presented in Table 8.4, taxicab operations might be made more productive through efforts to increase paid miles (only about half of the total miles are paid miles) and/or increasing the number of passengers per trip (the average of 1.3 is approximately the same as private auto occupancy for work trips). Such efforts would be helpful to two groups which have received increased attention in recent years. The elderly (60 years of age and over) who make about 22 percent of the total taxi trips and low income families (less than \$5,000 annual income) who make over 25 percent of the taxi trips.

Recognition of taxicabs as a viable form of urban public transportation and integration of taxicab service into the planning, programming, and funding process will be necessary to increase their effectiveness. Exclusion of taxis to date appears to be for traditional and political reasons rather than legal constraints. The following approaches might be considered in improving taxicab service:

- Alternative uses of the taxi and intermodal coordination (such as small package delivery, feeder service, etc.).
- Implementation of modified ordinances and fare policies, and shared ride options to encourage increased passenger loadings
- Consideration and evaluation of using taxicabs to serve different segments of the public transportation needs (handicapped, court-ordered access to medical services, and other programs where the practice has been to provide special needs using small vehicles).

8.8 IMPROVEMENTS TO RAIL RAPID TRANSIT

The scope of this course does not extend to the coverage of the various forms of fixed guideway mass transit since they do not involve operation on the urban street and freeway systems. Much of the passenger traffic carried by rail rapid transit systems operating and under construction in the United States will utilize the auto or some form of rubber-tired transit at one or both ends of the rail transit trip.

TABLE 8.4: TAXI SERVICE CHARACTERISTICS: MEDIAN VALUES

Miles per trip	5.85
Percent paid miles	49.5%
Passengers per trip	1.3
Trips per man-hour	2.15
Receipts: per trip	\$1.95
per man-hour	4.13
per mile	\$0.30
per paid mile	\$0.66
Phone orders per 9 hour shift	16.5
Percent of trips from phone order	88.2%
Driver commission per man-hour	\$1.79

Rail rapid transit (RRT) is the most capital-intensive form of urban transportation. Costs in subway construction exceed \$30-million per mile; even with relatively low cost at-grade and elevated construction per mile, costs are commonly \$10-million or more. Total capital costs range into the billions (BART, \$1.5 billion; Washington Metro is estimated to exceed \$3.5-billion). With such massive capital requirements and large-scale construction, implementation time following a decision to build a system exceeds 10 years.

Further, such large investments involve substantial costs when the alternative uses for the investment are considered. At today's prime interest rates and a long-term recovery period such as 50 years or more, each \$1-billion investment represents an opportunity cost of over \$70-million per year. Presuming that BART could pay operating expenses out of the fare box (most people believe it cannot), the \$1.5-billion represents an equivalent annual expenditure of over \$100-million.

With the high capital costs, RRT must achieve high daily ridership in order to achieve low costs per passenger served. In view of relatively low gross population densities of U.S. cities (typically 2,700 to 6,000 persons per square mile compared to, for example, 27,000 in Toronto), a large number of RRT trips will involve a change in mode of travel. Feeder transit services and park-ride facilities offer some potential for improving RRT ridership.

Provision of park-ride lots to facilitate passengers' transferring between auto and RRT will make the rail line-haul transportation more attractive for residents of outlying low density areas. Feeder bus, taxi, dial-a-ride, and kiss-ride provide further options

for improving RRT usage. The transfer point must be designed to provide for movement of pedestrians and the various private and public transport vehicles. Coordination of routes and schedules between the feeder and line-haul services is required if ridership is to be developed to its full potential.

"Stored-value" tickets which may be purchased for a specific amount, or a specific time period, stimulate more frequent use than when the fare is paid in cash for each trip. RRT systems are particularly well suited (by virtue of the limited number of stations) for computerized fare collection systems which can enhance the utility of prepaid-stored value tickets. Without delaying the fare, the computer subtracts it from the previous balance, and prints out the remaining value of the ticket.

Provision of convenience shopping opportunities in the terminal area can make it less time-consuming for passengers to pick up needed personal or household items without the need for an additional stop. While this does not affect the transit trip per se, it does contribute to a greater orientation of activity patterns toward transit. With proper attention to detail, these convenience retail establishments can be situated to serve the adjacent residential area as well, and thereby contribute to their economic viability.

8.9 FUNDING TRANSIT IMPROVEMENTS

Recent changes in the Capital Grants Program administered by the Urban Mass Transit Administration increased the permissible federal funding from two-thirds to 80 percent. However, the local contributions will undoubtedly continue to place a substantial burden on the financial structure of the local area.

TABLE 8.5. Local Sources of Capital Improvement Funds, 1971

	City	County	Transit District
General Fund	X	X	
General Obligation Bonds	X	X	
Property Tax	X		X
Sales Tax	X		
Utility Funds	X		
Loans	X	X	
Payroll Tax			X
Bonds (Other)			X

8.91 Sources of Capital Improvement Funds. The American Transit Association survey of United States transit properties found that the local area, (city, county, and/or transit district) was the source of almost 58 percent of all capital improvement funds in 1971.

The sources of capital improvement funds employed by local government as reported in the ATA survey are shown in Table 8.5. As might be expected, cities have had to obtain capital improvement funds for transit from the same sources they have traditionally used for other city activities.

8.92 Sources of Operating Subsidies. Caught between the ever-increasing costs of doing business on the one hand and declining ridership on the other, the industry has found itself in the position where operating revenue will not cover operating costs. Consequently, since 1963, the transit industry as a whole has been operating at a deficit. More important, however, is the magnitude of the trend itself. The deficit has grown larger each year with no indications of reversal.

Even the RRT systems are experiencing substantial deficits. A study conducted in 1972 by the Institute for Defense Analysis, entitled "Economic Characteristics of the Urban Public Transportation Industry," examined the financial conditions of the nation's rail-based transit system. Based on the combined total for all systems, revenues failed to cover operating costs, not including depreciation or debt service, by almost 16 percent.

Todd and Winfrey, in their study, "Financing Urban Transportation," made the statement that the public must have a clear understanding -- "that adequate mass transit systems can no longer operate as a profitable private or public business, but must be operated and financed as a public service for the benefit of the community (therefore, the community will be called upon to subsidize a portion of the capital needs of the facility, and perhaps, some of the operating expenses)."

It might be noted that the sources classified as general tax base sourced in Table 8.6 are the same sources as utilized to support transit capital improvements.

8.93 Current Funding Programs. Legislation recently approved provides 10.925 billion dollars over six years to assist urban mass transportation. Some 3.9 billion may be used for operating assistance. Authorized amounts would increase from 300 million in fiscal year 1975 to 900 million in fiscal year 1980. The federal share is not to exceed 80 percent for capital grants and 50 percent for operating assistance.

TABLE 8.6 Local Sources of Funds for Transit Subsidy, 1971

General Tax Base Sources	City	County	Transit District
General Fund	X	X	
Property	X	X	X
Utilities	X		
Sales Tax	X		
Payroll Tax			X
Automobile Based Sources	City	County	Transit District
License Tags	X		
Parking Meters	X		
Motor Fuel Tax	X	X	X
Auto Excise Tax	X		
Bridge Tolls	X		
Highway Fund		X	
Weelage Tax			X

In order to take advantage of such categorical grants, local government must commit monies for the local matching share regardless of other needs and demands for the use of local revenues. This frequently upsets the priority for capital improvement programs. Revenue sharing without restrictions on the use of the monies results in the funds appearing the same as locally raised revenues. Hence, expenditure decisions will be compatible with local priorities.

● Discretionary Funds. Section 3 of the Urban Mass Transportation Act of 1964, as amended, provides grants to assist cities in financing capital improvements on an 80% federal, 20% local matching ratio. Grants may be used for financing the acquisition, construction, reconstruction and improvement of mass transportation facilities. Eligible facilities include the purchase of buses, benches, passenger shelters, route markers, bus maintenance facilities, administrative offices, and stations or terminals (including the purchase of land). Monies under Section 3 are available on a discretionary basis (not allocated or apportioned to states or cities) to be determined by the Secretary of Transportation. No state may receive more than 15% of the total monies appropriated over the aid year period.

● Formula Allocated Funds. Section 5 of the National Mass Transportation Assistance Act of 1974, created a new program of Federal

assistance to urban mass transportation systems through grants which may be used by the recipients either for capital (80% federal, 20% local match) or operating assistance (50% federal, 50% local match). These funds are available to urbanized areas only and are allocated on a formula basis established by the Congress. For cities over 200,000, the Governor, responsible local officials, and operators of publicly-owned mass transit services, with concurrence of the UMTA, shall designate the recipient. For areas under 200,000 population, the Governor or his designatee is the recipient.

● R & D Funds. Section 6 of the Urban Mass Transportation Act of 1964, as amended, provides for research, development, and demonstration projects in all phases of urban mass transportation including the development, testing, and demonstration of new facilities, equipment, techniques, and methods to improve public transportation. The Secretary of the Urban Mass Transportation Administration approves grants under this section on a project-by-project basis. Anticipated nationwide funding for Section 6 for FY76 is \$67.3 million.

● Planning and Technical Study Funds. Section 9 of the Urban Mass Transportation Act of 1964, as amended, makes funds available for public transportation planning and other technical studies. The Urban Mass Transportation Administration apportions grant funds directly to cities with a population over 200,000. Funds are made available on a discretionary basis to cities with a population of less than 200,000. Activities assisted under this section may include (1) studies relating to management, operations, capital requirements, and economic feasibility; (2) preparation of engineering and architectural surveys, plans, and specifications; (3) evaluation of previously funded projects; and (4) other activities. Funding is available for projects under this section on an 80% federal, 20% local match.

● Elderly and Handicap Funds. Section 16b(2) of the Urban Mass Transportation Act of 1964, as amended, provides grants to provide for the transportation needs of the elderly and handicapped. Only private non-profit organizations are eligible to apply for these capital expenditures (the 20% matching funds must be furnished by the applicant from non-federal sources). Private non-profit organizations applying for capital assistance must provide service within a recognized "urban area" (a municipality having a population of not less than 5,000 persons according to the 1970 census). This does not preclude operation in a rural area as long as the origin and/or destination of the service is in an urban area.

● Urban System Funds. The 1973 Federal-Aid Highway Act permits cities to utilize their Federal-Aid Urban System funds for the pur-

chase of buses. In addition, funds from any Federal-Aid System may be used to construct preferential bus lanes, passenger loading areas and parking facilities along Federal-Aid routes. Section 142 projects are 70% federal, 30% local match.

- Rural Public Transportation Funds. Section 147 of the Federal-Aid Highway Act is a demonstration grant program which provides funds to encourage the development, improvement, and use of public transportation systems within rural areas, in order to enhance access of rural population to employment, health care, retail centers, education, and public services. Projects may be funded 100% by the Federal Highway Administration; however, no more than 30% of project funding may be used for operating expenses. The Washington office of the Department of Transportation will make a final selection of projects to be funded from available appropriations. Available funding under this program is \$9.65 million nationwide for FY75.

8.94 Planning Requirements. In accordance with the FHWA and UMTA intent to combine procedures for urban transportation planning, a regulation [39 FR 29660 (1974) - Urban Transportation Planning] annual review of the status of planning in the area and determination of eligibility of the area will include, but not be limited to:

- Existence of a Metropolitan Planning Organization, designated by the Governor,
- Existence of an effective decision-making process,
- Existence of an adequate, on-going transportation planning process consistent with the planned development of the urban area,
- Existence of a Transit Development Program resulting from the transportation planning process with an endorsed program of Section 5 projects,
- A finding of current validity of the transportation plan by the Metropolitan Planning Organization
- Existence of an adequate unified work program, and
- Existence of a current and valid agreement establishing responsibilities for carrying out transportation planning.

No project will be approved unless it is developed through the continuing, cooperative and comprehensive urban transportation planning process and included in plans and programs for a unified or officially coordinated urban transportation system consistent with the planned development of the urbanized area. Prior to project approval, determina-

tion will be made that the area has met the planning requirements of the Act and that the project is included in the approved annual program of projects.

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CHAPTER 9

BICYCLING AS AN URBAN TRANSPORTATION MODE

SESSION OBJECTIVES:

1. *To identify the demand for and effects of bicycle usage;*
2. *To examine the various alternatives for increasing the safety and efficiency of bicycle use in urban areas;*
3. *To identify the essential considerations for management decisions relating to bicycle facilities.*

9.1 INTRODUCTION

The bicycle was a form of intra-city travel prior to the time of the motor vehicle. However, when the automobile became established as the chief method of urban transportation, the bicycle remained principally as a means of mobility for children as they passed through graduated stages from the tricycle, to the bicycle, and ultimately, to the family car. However, because of a renewed interest in physical fitness, a concern for environmental well-being, and, perhaps most importantly, a rapidly-decreasing supply of available transportation fuel, the bicycle has emerged once again as an alternative for conquering the problems associated with concentrated travel in the urban area.

The magnitude of this movement is reflected in recent sales figures for new bicycles which, at present, outnumber the sale of automobiles in the United States. This trend does not appear to be reversing, nor does a saturation point in bicycle ownership seem apparent. It is expected that bicycle sales will eventually stabilize near the 11 million units per year rate.

TABLE 9.1

U.S. Bicycle and Automobile Sales

Year	Bicycle Sales, in millions	Automobile Sales, in millions
1968	7.5	10.0
1969	7.1	9.7
1970	6.9	8.1
1971	8.9	10.7
1972	13.7	11.0
1973	15.2	11.4

Unfortunately, the bicycle does not blend well with other types of traffic, due mainly to the differential in bicycle and vehicular speeds and the contrasting sizes of the vehicles.

To date, various communities have recognized the need for bicycle facility planning and construction. There exists, however, little uniformity among the plans so far suggested.

Probably the most comprehensive report and one which reviews the experiences of many individual bicycle plans is Bikeways--State of the Art--1974, published by the Federal Highway Administration.

9.2 BICYCLE PLANNING

Bicycle planning is a new activity for transportation management in many of the urban areas. In many respects bicycle planning is similar to the planning of the street network. However, there are some major points that should be reviewed briefly.

9.21 Types of Bicycle Riders and Trips.
Most bicycle riding activities may be classified into the following categories:

- Neighborhood riding is done mostly by young children. Except for school trips, riding is often purposeless and is not limited to a specified route.
- Recreation riding is a leisure time activity for all ages. Routes should be considered which provide a minimum of conflict with vehicular traffic. Aesthetics are important, and attention should be given to providing pleasing visual impressions whenever possible.
- Commuter riding is increasing due mainly to parking difficulties, energy conservation, and physical fitness reasons. Routes of this type should be as direct as possible between work and living areas. Aesthetics becomes less important but the need for parking facilities at the work trip end increases.
- Sport riding and touring with sophisticated, light-weight bicycles usually requires facilities built for higher speeds and longer trips. Facilities of this type may not be entirely compatible with those for a more leisurely type of riding.

9.22 Various types of facilities may be combined to form the bicycle network such as local, collector, and arterial streets form the urban street network. Various methods of describing these facility types exist; however, the following appear to be the most common.

- Class I (Bike Path or Protected Lane)--A completely separated right-of-way designated for the exclusive use of bicycles.

- Class II (Bike Lane)--A restricted right-of-way designated for the exclusive or semi-exclusive use of bicycles; through motor vehicles are not permitted. Vehicle parking and access to property as well as pedestrian access to parked vehicles are allowed.

- Class III (Bike Routes)--A shared right-of-way designated as such by signs placed on vertical posts or stenciled on the pavement.

9.23 Bicycle Network Planning--Having established the types of trips to be accommodated and the various kinds of bicycle facilities, the following network planning procedure can be considered for the development of a comprehensive bicycle plan.

Step 1. Conduct inventories of existing facilities. Determine traffic volumes, speeds, and parking conditions on street facilities, and physical dimensions of the street. Explore the availability of semi-private and municipal rights-of-way such as utility and abandoned railroad rights-of-way and areas around lakes and reservoirs.

Step 2. Forecast demand for bicycle facilities. Conduct origin-destination studies or in-home interviews as to bicycle usage according to number of riders in family, number of bicycles, and number and type of trips. Based on areas with similar socio-economic characteristics, project trips between these zones as well as intra-zonal travel. Consider amount of generated traffic by addition of a new facilities.

Step 3. Establish planning and design standards.

Step 4. Design bikeway network and facilities.

Step 5. Prepare alternate plans where more than one alternative exists.

Step 6. Evaluate plans. Utilize governmental personnel responsible for city planning, traffic operations, street maintenance and transit, and parking management for review. Involve citizens from bicycling, public service, environmental and other interested groups.

Step 7. Select final plan.

Step 8. Implement plan.

Step 9. Evaluate results. Evaluate use and operations of constructed and marked bicycle facilities as input for future bicycle planning.

The comprehensive bicycle plan should offer similar service to all bicyclists within the confines of the planning area. In addition, the plan should provide continuous routes connecting the smaller community bicycle systems. This is the rationale behind the "honeycomb" system as suggested by the City of Dallas in which Class I Bicycle Paths on exclusive right-of-way form the honeycomb, providing a network for travel between individual zones as well as around the zone. Within each zone, Class II Bicycle Lanes on city streets provide for movement within the zone and outward to the Class I facilities. Class III Bicycle Routes in turn provide access to higher type facilities.

9.24 Potential for Reducing Demand. A potential bicycle market for urban areas can be estimated based on the data presented by Everett (27). Everett's data indicate that the commuter bicycle trip is feasible up to six miles one way. Thus, assuming that there is a total demand of 100,000 trips per day in an urban corridor, that 40 percent of the people would be willing to divert to the bicycle, and further that the peak hour is 10 percent of the ADT, the potential peak hour bicycle demand is

$$(100,000)(.4)(.4)(.1) = 1600 \text{ trips}$$

This represents about one freeway lane or 50 loaded buses or 22-75 passenger transit vehicles. Thus, the potential impact of the bicycle on the transportation planning process could be rather significant.

However, bicycle riding is a fair weather activity for most persons. During periods of heavy rain, wind, snow or other adverse weather conditions, bicycle riding will be reduced substantially. Since the transportation plan is usually based on the tenth highest hourly loading during the year, there are relatively few areas of the country where year round cycling exists. For this reason, the impact of the bicycle on the need for other transportation modes will be nil except in a very few special instances. There is a need for bicycle facilities, but the reduction in vehicular traffic demand will in most cases, be "icing on the cake" rather than having the effect of reducing the need for other transportation facilities. For this reason, care must be exercised to insure that the vehicular capacity of existing streets not be reduced by the proposed bicycle facilities.

The fact that bicycle use does not reduce the demand for other transportation facilities should not be misconstrued to mean that there is not a real need for bicycle facilities. The increased use of bicycles combined with efforts to get more vehicular capacity from existing streets will undoubtedly lead to greater vehicular - bicycle conflicts and accidents. Additionally, bicycle traffic mixed with motor vehicle traffic impedes flow and reduces capacity.

The transportation manager should include bicycle planning as a part of the overall transportation system.

9.3 BICYCLE FACILITY DESIGN

9.31 Design Guidelines. The FHWA publication "Bikeways - State of the Art - 1974" presents a detailed discussion of design requirements of all types of facilities. This publication should be available to every city as a reference document for planning and design of bicycle facilities. Further, the city should develop its own design standards for bicycle facilities, similar in many respects to city street design standards. Major items to be included in bicycle facility design standards are:

- Design Speed
- Horizontal Curve Controls
- Minimum Facility Cross Sections
- Maximum Grades
- Lateral and Vertical Clearances
- Intersection Layouts
- Grade Separations

9.32 Intersection Design. Regardless of the type of bicycle facility, conflict with vehicular traffic is inevitable at intersections. Turning bicyclists must cross vehicle paths, and turning vehicles must cross bicycle paths. There are two general approaches to partially resolving problems at intersections.

- Channel the bike lane off the street so that it operates as a parallel or adjacent intersection.
- Terminate the protected bike lane immediately prior to the intersection, placing bicycles back into the traffic stream.
- For a more detailed treatment and more revolutionary treatments, refer to BIKeways--STATE OF THE ART--1974 by FHWA.

9.33 Grade Separations. Where vehicle volumes prevent at-grade crossings by bi-

cycles, grade separations may be constructed. Underpasses are preferred somewhat due to lower vertical clearances for bicycles than for vehicles. Also, the down-grade approach to the underpass allows the bicyclist to gain momentum in order to carry him up the other side. Underpasses, however, need to be well-lighted and should provide line-of-sight throughout, if possible.

9.4 OPERATION AND CONTROL

The operational controls for bicycle facilities serve two fundamental purposes:

- To delineate the bicycle facility; and
- To insure the safety of the cyclist.

For on-street bicycle facilities, the regulatory devices for vehicular control will generally serve for cyclists as well. The primary control requirement is therefore one of delineation of the bicycle lane. For separate bicycle facilities, the safety of the cyclist is the primary concern. Warning signs and intersection right-of-way control devices are the principal controls.

9.5 BICYCLE PLAN REVIEW

The following planning and design points are suggested for special attention in the review of bicycle plans.

9.51 Planning.

- System Continuity. Considered here should be whether or not the system is indeed a comprehensive system providing for a variety of trip lengths and purposes or whether those improvements being made will only benefit certain areas.

- Implementation Scheduling. All of a proposed bicycle system cannot be constructed or implemented immediately. Where possible, those elements that will benefit the most people first should be given precedence. For example, building a bike path around a lake should probably be done after bicycle access facilities are provided to the area.

- Effects on Vehicular Capacity of Facilities. Either Class II Bike Lanes or Class III Bike Routes reduce the effective street width usable by vehicular traffic. Care should be taken in reviewing bicycle plans to retain sufficient capacity of streets within a given corridor.

9.52 Design

- Lane Width and Lane Location for Class II Bike Lane facilities should be carefully

reviewed. Lane width must be adequate to prevent bicycles from encroaching upon the traveled roadway. This is especially important in the event that two-way bike lanes must be used. If street width is not sufficient to allow adequate bicycle lanes, route relocation should be considered.

- Grades on Class I Bike Path facilities which parallel street facilities should be less than those on the street facility to encourage use of the bike path. Not only the steepness, but also the length of grades, is important.

9.53 Operation

The bicycle plan review should include an operational analysis of the plan with respect to safety of the cyclists. Bicycle facility sections which are not open to view of passing motorists may be an invitation to criminal acts and should also be considered in the plan review.

9.6 COST OF BICYCLE FACILITIES

The cost of bicycle facilities varies dramatically with the type of facility. The cost data presented below were obtained from the City of Dallas and reflect 1974 costs. Approximately half of the maintenance cost is for security surveillance.

TABLE 9.2. Bicycle Facility Cost Per Mile (26)

Type of Facility	Initial Cost (1975 Base) Excluding Land	Annual Maintenance Costs
Bikeways	\$30,000+	\$1,500 (Asphalt) 950 (Concrete)
Protected Bicycle Lane On Street	\$ 6,000	\$ 600
Unprotected Bicycle Lane On Street	\$ 3,000	\$ 300
Bike Route	\$ 700	\$ 100

9.7 FUNDING OF BICYCLE FACILITIES

The following quote comes from the publication, "The 1973 FEDERAL-AID HIGHWAY ACT--AN ANALYSIS."

Bicycle and Pedestrian Facilities--The States may build separate or preferential bicycle facilities and walkways in conjunc-

tion with non-interstate federal-aid highway projects and will be funded from funds for the system on which the facility is located. The Federal share of the cost of such projects will be 70 percent, but not more than \$2 million per state and \$40 million per fiscal year may be used for them. Funds authorized for other federal road programs, e.g., forest and public lands highways, parkways, etc., may also be used for this purpose.

In addition, Interstate funds can be used for bicycle facilities which are included in new construction. Federal funds for bicycle and pedestrian facilities are limited to \$2 million per year for each state. The non-interstate funds can be used for 70 percent of the cost with the remaining 30 percent coming from local sources.

All bicycle facilities must meet the following criteria:

- The safety of the bicyclist, pedestrians, or vehicular traffic must not be impaired;
- The proposed facility must be a part of and connect to elements of the existing or planned system;
- The facility must be under the jurisdiction of a public agency; and
- There must be sufficient existing or projected demand to render the proposed facility cost-effective.

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CAPACITY ORIENTED ALTERNATIVES

Sessions 10 through 14 of this course deal with the various capacity-oriented alternatives that may be implemented through transportation management processes to improve urban transportation. Although "capacity" is most frequently associated with the number of "vehicles" that may be accommodated by a traffic facility, the intent in these sessions is to address the "people" handling capability of the system. It should be understood, however, that we cannot totally disregard capacity in terms of vehicles, because vehicles carry people. Thus, the objective is to discuss alternatives that increase the efficiency of transportation facilities with particular emphasis on the transportation of persons and goods on these facilities.

The five sessions relating to capacity-oriented alternatives include improvements in urban goods movement, pedestrian facilities, traffic operations, freeway operations management and the importance of coordination in the planning/design/operation of a street network.

CHAPTER 10

IMPROVING URBAN GOODS MOVEMENT

SESSION OBJECTIVES:

1. *To identify the general traffic congestion effects of goods and services movements in the high-density urban central business district.*
2. *To present alternatives for the improvement of traffic operations and the movement of goods and services in the urban central business district.*
3. *To recommend guidelines for the development and consideration of alternatives to improve the movement of goods and services in the central business district.*

10.1 INTRODUCTION

The movement of goods and services in the urban area is a major element of the transportation system. Trucks delivering goods and providing services to the business community constitute a major part of the traffic using the street system. Because of the concentrated business activity, the central business district experiences the greatest impact of goods and services movement activity.

Although the movement of goods and services occurs throughout the day and night, the majority of the activity occurs during daylight hours, and, further, studies have shown that the major movements occur between the hours of 10 a.m. and 2:30 p.m. (4). This implies that during the peak traffic periods, truck movements are relatively lower than during other periods of the day. This is obviously an advantage in providing peak hour transportation, but to what extent is truck traffic reduced, and what percentage of the CBD peak hour is trucks? A study of truck movements in the city of Dallas (2) showed that approximately 12,000 trucks entered the CBD during a 12-hour period. This number represented 10% of the total traffic entering the area. During the morning peak period of 7:30 to 8:30 the truck count showed approximately 800 units entering the CBD. If we assume that 12% of the total traffic (120,000 vehicles) entered during the morning peak, then trucks would be roughly 6 percent of the peak hour traffic. Equating this to passenger cars for capacity comparison, trucks use approximately 12% of the availability capacity, assuming that the system is operating at capacity

The delivery of goods and services in the CBD area of major cities is a large-scale, intensive activity. Therefore, it is necessary that we know more about the system. It is easy to assume that the problem is principally the handling of freight. The study in San Francisco (4) showed that 35,000 daily stops were made in the downtown area; however only 15,000 stops were for loading or unloading freight. As an illustration of the types of activities, 9000 stops in the Dallas CBD included 1500 stops by beverage trucks, 500 stops by U.S. Mail vehicles, 1000 stops by armored cars and security carriers, and 500 stops by service vehicles.

One of the major problems relating to the movement of goods and services within the CBD is in the pick up and delivery. Most buildings in the area do not have sufficient off-street facilities for pick up and delivery and, therefore, most of the activity takes place at the curbside. The proportions will vary from city to city, but it is estimated that 80 to 85% of the pick up and deliveries are made from curbside points.

There are other characteristics of CBD trucking activity that are pertinent to an understanding of the goods and services movement within the city.

- About 90% of all CBD stops are for the purpose of picking up or delivering goods. Service calls represent 5 to 10% of total stops.
- About 70% of all stops are made by private fleet vehicles.
- About 20% of all CBD deliveries also have their origin within the CBD.
- The average duration of a commercial vehicle stop in the CBD is around 25 minutes.
- Most goods and services stops are made at the curb. Only about 15 to 20% of the stops are made in off-street facilities.

10.11 The Problem as Viewed by Interested Parties. The problem of transporting goods and services, like other complex urban problems, involves other than the governmental units responsible for the transportation system. These include the city, the property owner, the tenant and the carrier.

10.11.1 The City. Development within the CBD represents a substantial investment of both private and public monies; the city tax base depends heavily on this investment. In

order to sustain this concentrated development, the city must provide for all necessary traffic movements--pedestrians, automobiles, and buses as well as trucks. Most delivery stops in the CBD occur at the curb within the city right-of-way. The city has only a limited right-of-way area which must accommodate a multiplicity of users. Thus, the city experiences a significant cost in providing curb loading space.

10.11.2 Building Owners and Managers. Building owners and managers are confronted with problems relating to goods distribution on a regular basis. However, many downtown buildings are not designed to functionally serve the loading needs of the building. As a result, short range solutions to problems in these buildings may be limited.

Many building owners and managers believe that the city should take the lead in finding solutions to the goods distribution problem. Any change in existing procedure that would increase either the legal responsibility or the cost to the building is generally considered as undesirable by building owners and managers.

10.11.3 Building Tenants. Building tenants generally do not have extensive exposure to the problems associated with goods distribution. These individuals are aware that they are able to place an order and that the order will be delivered directly to their office within a reasonable period of time. This arrangement is satisfactory to the tenant, and the tenant has no reason to be aware of any difficulties experienced by the carrier between the time the order was placed and the time at which it was delivered. Generally, distribution of goods and services is a very minimal consideration in the tenant's decision concerning where to rent office space. However, if problems arise in having deliveries made to the CBD, this could become a very definite factor in the rental of downtown floor space.

10.11.4 The Carriers. Since the carriers are responsible for making deliveries into the CBD, this group is acutely aware of the problems associated with the goods distribution process. The carriers are generally not satisfied with existing systems and fear that future plans may place more restrictions on their operation.

The carrier is exposed to virtually all aspects of the goods distribution problem. Once in the downtown area, finding a legal loading space within reasonable proximity to his destination is a major problem. Once a loading space has been found, the carrier must gain entrance to the building and locate a consignee to accept the shipment. Quite obviously, these difficulties result in a decrease in the efficiency of the

carrier's operation in the downtown area.

10.11.5 Other Street Users. Other street users, principally the auto (private and taxi), transit and pedestrians, experience serious conflicts with trucks and other vehicles involved in the movement of goods and services. A parked vehicle, whether in a designated parking space or a loading zone, constitutes a deterrent to traffic movement on the street. The situation is further aggravated by the size of many of the delivery vehicles. They tend to further restrict movement and sight distance. Also, trucks maneuvering into loading zones generally block traffic in through lanes.

When loading zones are full, trucks sometimes occupy space allocated to transit stops, a practice greatly detrimental to good transit service. In addition, transit vehicles maneuvering around trucks in a confined space results in delay and poor traffic operations.

The pick up and delivery of goods at the curb-side is in direct conflict with pedestrian movements along the sidewalk. Conflicts may be minor during off-peak periods, but pick up and delivery during peak pedestrian flow may be significantly detrimental to pedestrian service.

Thus, the transportation manager faces the dilemma of coordinating a major element of the transportation system, the movement of goods and services, to the best interest of several facets of the business sector, with a minimum of conflict with transportation elements, and without disrupting the substantial tax base that makes all urban operations possible. There are a number of alternatives available to him, and they generally can be classified as long-range and short-range alternatives.

10.2 LONG-RANGE IMPROVEMENT ALTERNATIVES.

The alternatives classified in this category are placed there because of their anticipated cost, drastic changes in present way of doing things, and the long lead time required for major construction efforts.

10.21 Zoning Regulations. One obvious solution to the congestion effects of pick-up and delivery of goods and services is the provision of off-street facilities. Zoning regulations can be used to require sufficient off-street loading space, but, understandably, these requirements cannot be made retroactive. They can only apply to new or modified construction. Thus, establishing regulations for the provision of off-street facilities is a long-range alternative.

Zoning regulations (or other similar regula-

tory measures) are being used fairly effectively in some cities, and should be instituted in others. Figure 10.1 is an illustration of the relationship of gross floor area to the number of off-street loading spaces required for office buildings in a number of U.S. cities. Figure 10.2 illustrates similar requirements for retail department stores. The Design Level I provides sufficient loading spaces that the demand during the peak time of the year does not exceed the availability of spaces more than 25%.

Design Level II provides sufficient space to accommodate the peak period of the day during the peak time of the year (generally the six-week period before Christmas).

The development of requirements for off-street loading facilities is based on average truck stop rates for various land uses. These rates (number of stops per 10,000 square feet of floor space) are given in Table 10.1

TABLE 10.1. Rates Used to Estimate Daily Truck Stops Generated By Downtown Land Uses

Land Use	Daily Truck Stops Generated Per 10,000 Square Feet of Floor Space
Office	2.1
Retail*	7.0
Department Stores	2.4
Hotels	1.0
Parking	0.0

* average of all retail uses

10.22 Multi-Level Transportation Facilities. Many cities have long-range plans for the development of the central city area in a multi-level concept which will provide vertical separation of the various conflicting activities in the highly concentrated CBD core area.

In such an arrangement, there would conceivably be at least three levels, and perhaps more, depending on the various transportation modes serving the area. A typical system may provide pedestrian movements on an overhead system, passenger cars, taxis, jitneys, etc. at the ground level, and truck and service vehicles below ground level. Where rail-rapid transit serves the area, another level is added, and pedestrian move-

ments may be shifted to underground locations for easier access to the transit system.

10.23 Consolidated Delivery. Consolidation of deliveries could easily be classified as a short-range alternative, but it has been placed in the long-range category because 1) it would require a major alteration of the current procedure, and 2) it would possibly require the development of a peripheral receiving/consolidating facility and an operational system of delivery vehicles.

Under this concept goods destined for the CBD would be delivered to the central facility where they would be consolidated for delivery. This approach has the theoretical advantage of reducing the volume of truck traffic and the number of stops at a given facility in the CBD.

This concept is more applicable to the "for hire" carriers than it is to private carriers. Since private carriers constitute two-thirds to three-fourths of the total delivery/service vehicles in the CBD, this concept has limited potential. In addition, many of the "for hire" carriers route their vehicles so that they enter the CBD fully loaded and leave the area empty. In these cases, consolidated delivery would offer little advantage, but would increase the cost associated with delivery.

One major problem with private carriers is that drivers are also salesmen. Beverage delivery is an excellent example. It is impractical to consider the possibility of a driver carrying his competitor's product. However, there are some revolutionary changes that could be made to reduce the congestion effects of providing vending machine services. Typically a driver parks his vehicle and services all of the machines in a given building. For large buildings this may take several hours. By using containerization technology, a service module could be deposited at the building by a service truck provided expressly for the purpose of hauling containers. The sales/service man could utilize bicycle, motorcycle, or public transportation to make the service stop, utilizing supplies provided in the container.

10.3 SHORT-RANGE IMPROVEMENT ALTERNATIVES.

Certain improvement alternatives lend themselves to low-capital investments, with quick but perhaps less significant results. However, these are the alternatives which provide the immediate relief and should be considered on that basis.

10.31 Consolidate Receiving. One of the major problems in the delivery of goods in the CBD is the time required to effect delivery. Where there are several tenants in a building, the delivery driver must unload

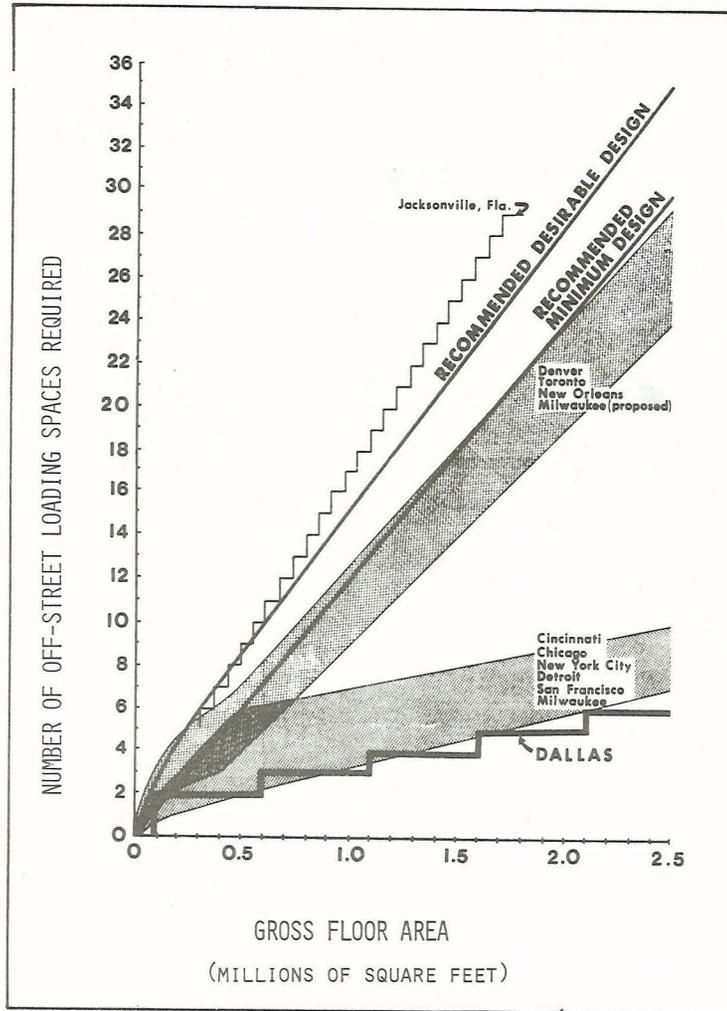


FIGURE 10.1. OFF-STREET LOADING REQUIREMENTS, OFFICE BUILDINGS

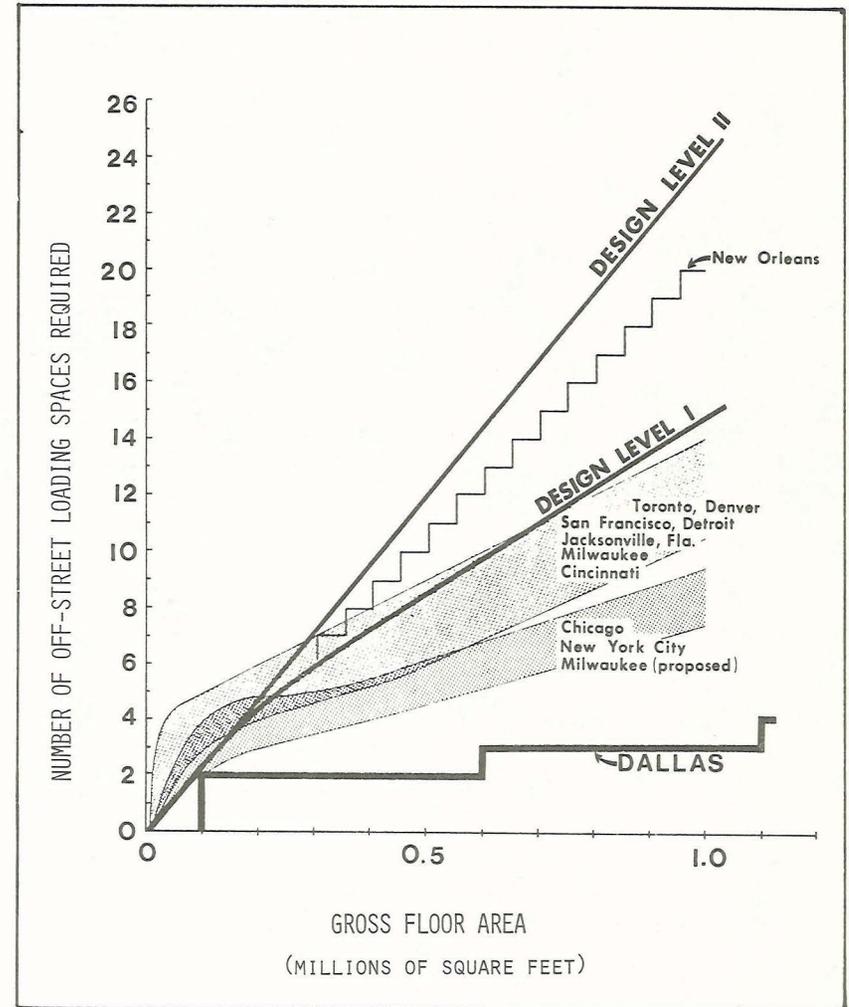


FIGURE 10.2. OFF-STREET LOADING REQUIREMENTS RETAIL DEPARTMENT STORES

Source: "Off-Street Truck Loading Facilities in Downtown Areas: Requirements and Design," Christiansen, D. L. and Holder, R.W., TTI

the shipment, transport the shipment to the proper floor and then find someone to accept the shipment. Under the consolidated receiving concept, all goods destined for a given building are delivered to one central location where a receiving clerk is on duty to accept deliveries. Distribution of goods within the building is then performed by members of the receiving staff.

This approach greatly reduces the time a carrier must spend in completing a delivery. As a result, a loading space is able to serve more vehicles per day. This concept does involve a cost to the businesses served and may create some legal problems. The general attitude is that the city cannot force buildings to implement consolidated receiving, but it can encourage implementation through the Central Business District Association. If the city has an established fee for loading zones, then it could provide an incentive by reducing fees where consolidated receiving is practiced.

10.32 Night Delivery. The delivery of goods and services at night is frequently proposed as a means of reducing traffic congestion in the downtown area. Although there are a number of obvious benefits to the transportation system, this alternative has a number of disadvantages.

- Legal authority to enforce night time delivery is a major step.
- Major work schedule adjustments must be made by the carrier.
- Many deliveries and service calls require personal representation of the receiver. This may require additional employees, and, as a result, increase operating costs.
- Many deliveries and services are time-dependent, that is, they must be provided during the course of normal business hours.
- Security problems likely will be encountered.

Where practicable, night delivery should be implemented because it does offer significant advantages. The transportation manager should consider this as a voluntary rather than a forced measure. Certainly, the city should implement service and maintenance operations at night within its own jurisdiction to their fullest measure.

10.33 Improve Curb-side Loading Zone Operations. In most cities of the United States, the major portion of the delivery of goods and services takes place in a curb-side loading zone. Realistically, this cannot be altered substantially during the short run. There are, however, some short-term alternatives that may improve the efficiency of curb-side loading zone operations. First,

the problems associated with loading zone efficiency are time of occupancy, space, legality of use, and traffic conflicts.

10.33.1 Time of Occupancy. The time that one vehicle occupies a loading zone is obviously critical. Imposing limited time of occupancy will force carriers and receivers to improve the efficiency of their operations and improve the utilization of the curb space. It should be noted, however, that enforcement will be difficult.

10.33.2 Space. The amount of curb space devoted to loading zones is important, but the location is even more critical. One delivery vehicle parked at curb-side can reduce the effective street width for the entire block. It is recommended that loading zones be concentrated on lesser traveled streets even though this may result in increased distances that the carrier must travel on foot. If planned properly, the carrier will not have to cross a street with a hand delivery cart.

Where curb-side loading zones are permitted, sufficient space should be provided where practicable. Insufficient space results in excessive circulation attempting to locate a vacant space, and this only adds to the congestion. If there is a decision to be made regarding the priority of delivery vs. curb-side parking, then delivery should be given the higher priority.

10.33.3 Legality of Use. One major deterrent to the efficiency of curb-side loading zones is the use by unauthorized persons or vehicles. Without proper regulation, they may be used merely as parking spaces for service or delivery vehicles. This is particularly true where cities charge a fee for the installation of a loading zone. Building owners or merchants consider the loading zone as proprietary and use it as a parking space. For this reason it is not advisable to operate on the fee concept.

Regulation of the use of curb loading space is difficult, both in terms of time of occupancy and in terms of the legality of vehicles that do use the space. One approach to assuring the legality of vehicles using loading zones is to allow only those vehicles displaying a commercial sign on the side of the vehicle. Still another approach is to issue loading zone use permits. This latter approach would give the city an opportunity to determine the true need of loading zone space as opposed to parking space. For example, messengers, pharmaceutical deliveries, and other small in-hand deliveries need not occupy a loading zone when their delivery can be effected just as easily from a short-term parking space a greater distance from the building.

10.33.4 Traffic Conflicts. In many instances major problems with loading zones occur during the peak periods when the loading zone occupies space that is needed for moving traffic. It appears feasible that some loading zones, particularly those on principal thoroughfares in the CBD, can be regulated by time of day. Prohibiting use of the loading zone during peak periods would permit the total street width to be devoted entirely to handling traffic during the peak periods.

10.4 IMPLEMENTATION GUIDELINES.

Because the problems associated with the movement of goods and services within the high-density urban area involve at least three different groups -- the city, the carrier, and the customer -- there are special considerations to the implementation of improvement alternatives. Similar to variable work hours and other improvement alternatives, the transportation manager must enlist the support and cooperation of the business sector in solving the problem in the best interest of all concerned. The following are points that should be considered in pursuing development and implementation of an effective program for improved movement of goods and services in an urban area.

- Plan and execute the various studies necessary to determine the demand, the availability, the use, the effectiveness, and the effects of loading facilities. This should include both off-street and curbside facilities.

- Organize or take advantage of existing organizations that will provide a forum for definition of the problems and the coordinated planning and execution of solutions to problems related to the movement of goods and services.

- Based on an analysis of problems associated with goods movement within the city, select and implement alternatives that are acceptable to the business sector, and hence will gain their support in the overall improvement of transportation within the city.

- Encourage the establishment of an enforcement program that will insure maximum effectiveness of space allocated to the movement of goods and services.

- Establish procedures that will result in the routine or scheduled servicing of utilities in the CBD area so as to minimize the disruption of transportation operations.

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CHAPTER 11

ALTERNATIVES FOR IMPROVING PEDESTRIAN FACILITIES

SESSION OBJECTIVES:

1. *To stress the importance of pedestrian considerations in the management of urban transportation.*
2. *To identify ways in which pedestrian problems may be resolved.*
3. *To suggest guidelines for the consideration and implementation of pedestrian improvement programs.*

11.1 THE PEDESTRIAN PROBLEM

Pedestrian movement is the most fundamental transportation mode - virtually every trip begins and ends as a pedestrian movement. Yet, accommodations for pedestrian movement perhaps receives the least consideration of all transportation modes.

In the automobile era, pedestrian movement has been minimized due to personal preference. As a convenience to the public, drive-in services, such as banks, restaurants, cleaners, and various utility payment offices have been provided. Parking facilities have been built in close proximity to jobs, retail stores, entertainment, and services to reduce the need for walking. In summary, we have used this age of technology to minimize our travel desires and needs that must be satisfied by the walking mode. Along with this has come the general reduced emphasis on the provision of pedestrian facilities.

Pedestrian problems arise primarily as a result of mixing with other modes. Without the protection of a mass of metal to increase the momentum and serve as armor, the pedestrian is at a disadvantage in conflict with other modes. As a result, there is a loss in efficiency, convenience, and safety.

Even a cursory review of accident statistics shows that the pedestrian safety problem is very significant. Using 1973 nation-wide statistics, the following significant points are made:

- 2.2% of all urban motor vehicle accidents involved pedestrians.
- 30.6% of all urban fatal accidents involved pedestrians.
- 26% of fatal pedestrian accidents involved children 14 or under.
- 25% of fatal pedestrian accidents involved

adults 65 or over.

- 70% of all pedestrian accidents occurred while pedestrians were crossing the street.
- 40% of all pedestrian accidents occurred while pedestrians were crossing at the intersection.

From these statistics, it is obvious that pedestrian safety is a major problem. Further, the problem relates to the young and the old, and to pedestrian errors as well as driver errors.

11.2 CORRECTIVE APPROACHES FOR PEDESTRIAN PROBLEMS

The pedestrian mode is a significant part of the urban transportation system, and there are pedestrian problems that must be solved in order to achieve and maintain a viable urban transportation system. These problems relate to the planning, design, and operations aspects of transportation. Safety must be a principal criterion, but like other modes, the transportation manager must consider the general service aspects of pedestrian facilities in satisfying public need.

All things considered, the transportation manager must view the pedestrian problem in the traditional sense, that is:

- enforcement
- education
- engineering
 - planning
 - design
 - operation

The transportation manager can and should be involved at least indirectly in the enforcement and education phases of the overall problem, but he must assume full responsibility for the engineering phase.

From an engineering viewpoint, the pedestrian system consists of facilities that relate to vehicular movement in two general categories. These are:

- Vehicle - Dominant Facilities - Pathways that exist in, or share space dominated by vehicular movement, and
- Pedestrian - Dominant Facilities - Pathways that are reserved exclusively for pedestrian movement with no vehicular intrusion except in an emergency.

The primary example of an entire system of vehicle-dominant pathways is the parallel grid system of ordinary sidewalks that has grown out of years of common use of streets and roadways by both vehicles and pedestrians. Vehicle conflicts often occur at parking lot and alleyway entrances as well as normal street crossings. To the pedestrian, this system offers a coherent network of familiar paths. Directional orientation results from his perception of well-known visual landmarks and other points of reference. Pathways in the vehicle domain may also offer him the most direct route to his destination due to the way in which pedestrian activity centers are distributed to suit the vehicular network; line-of-sight visual contact during combination of pedestrian and vehicular movement within the same space usually works to the detriment of both users. To the motorist, pedestrian activity is the cause of congestion and delay. To the pedestrian, his safety is jeopardized every time his path crosses a vehicle path. Restriction of his pathway to be parallel to the street network often causes him to make long walking trips to reach destinations which are, by direct measure, only a short distance from his origin node. In addition, he must endure noise and air pollution, and the visual and physical obstruction caused by cars and trucks.

On the other hand, the provision of separate, pedestrian-dominant pathways exclusively for walkers can yield benefits to both the pedestrian and the driver. Facilities such as separate walkways crossing above or below vehicular circulation can provide a safe, convenient, and comfortable environment for the pedestrian while freeing the driver from the nuisance and delay caused by the intrusion of pedestrians into the vehicle domain. Secondary benefits from separated walkways can accrue to other entities such as retail activities that abut the pedestrian paths.

Pedestrian systems may be further classified according to three basic types which are defined by the way in which pedestrians and vehicles are (or are not) separated.

- Integrated System - The common system of sidewalks and street crosswalks that now exist throughout practically every city. These are principally vehicle-dominant systems, and the upper range of pedestrian accommodation is by time separation, where alternately the pedestrian and the vehicle are given exclusive use of street space. Otherwise, pedestrians are afforded use of street space by law, and by the natural gaps in the traffic stream.

- Horizontal Separation - A specialized system for the exclusive or semi-exclusive pedestrian use of space in a horizontal plane with the vehicle network. This type is characterized by malls, semi-malls, and various exclusive sidewalk arrangements.

- Vertical Separation - A specialized system for the exclusive use of pedestrians, located either above or below the vehicular system. This type is characterized by tunnels, subways, skyways, overpasses, etc.

The various alternatives available to the transportation manager for the improvement of pedestrian operations within an urban area will be discussed in the order of the types of systems outlined above.

11.21 Integrated Systems. Because this system consists primarily of the vast network of pedestrian facilities now existing, and generally viewed as insufficient, the alternatives for improvements generally relate to spot improvements for upgrading the existing system. However, there are a number of planning and design practices that may be instituted to provide a better pedestrian system. A number of alternatives are:

11.21.1 Spot Improvements.

- Signal timing. Pedestrian signal displays may be installed, and signals may be timed more efficiently for pedestrian operations. Also, the specialized phasing, the "all-red" interval may be used to increase the efficiency of pedestrian flow and increase safety through the elimination of pedestrian-vehicle conflicts.

- Removal of obstacles. One of the major problems in high-density urban areas is the normal "clutter" that reduces the capacity and serviceability of pedestrian facilities. This "clutter" consists of functional objects such as newspaper dispensers, mailboxes, litter cans, fire plugs, sign posts, light posts, signal posts and other forms of street furniture. Even though these may be desirable or necessary items, their application or use may be regulated so as to reduce the interference with the pedestrian flow network.

- Changing curb radii. Longer radius-curves have been stressed for smoother vehicular flow. These long-radius curb returns tend to reduce pedestrian capacity and increase walking distances. By shortening the curb radius, particularly where turns are restricted, pedestrian flow may be improved.

- Widening Crosswalks. In the pedestrian system, as in the vehicular system, the intersection is the major capacity-limiting feature. For vehicular flow, intersection widening has proven to be an effective means of increasing street capacity. In the same manner, widening crosswalks may increase the capacity of the pedestrian system.

- Sidewalk Lighting. Although lighting may not increase the capacity of pedestrian facilities, its value in the safety and security of pedestrians is obvious. Lighting in other

areas such as pedestrian connections to recreational areas, shopping centers and other pedestrian generators permit drivers to see and avoid pedestrians.

11.21.2 Pedestrian Provisions in Subdivision and Street Design Standards.

- Sidewalks. Contrary to practice in recent years, sidewalks should be required in all residential areas, and on collectors and arterials where pedestrian movements are not restricted. These may be combined with provisions for bicycles. The street design standards should provide the design requirements for pedestrian facilities.

- Pedestrian easements. In the new concepts of subdivision layout, long blocks, cul-de-sacs and discontinuous local streets are recommended to deter vehicular movement. These same practices tend to discourage pedestrian and bicycle movements. With adequate planning of the pedestrian circulation system and with the provision of easements through long blocks and cul-de-sacs, pedestrian flow can be increased and vehicular travel reduced.

- Pedestrian circulation system. Pedestrian systems should be planned to connect with neighborhood shopping and public transit facilities.

- Residential neighborhood intersections. For vehicular traffic, the T-intersection has proven to be safer and operationally more efficient because of the inherent natural control feature and the fewer number of conflicting paths. For these same reasons T-intersections are preferred for pedestrian safety.

11.21.3 Pedestrian Features in Design.

- Refuge islands. On wide streets, it is desirable to design medians such that they serve the function of pedestrian refuge. Also, where intersections result in extremely long pedestrian paths, islands may be installed to channel traffic, reduce the exposure of pedestrians to traffic and give pedestrians an opportunity to cross one stream of traffic at a time.

- System continuity. The same concern for system continuity should be exercised for the pedestrian system as for the vehicle system. Sidewalks should be designed to approach the crosswalks, and pedestrian barriers may be installed to channel pedestrian traffic to the crosswalk.

- School Zone Planning. The Manual on Uniform Traffic Control Devices gives a brief but effective introduction to the planning aspects of effective control of pedestrian and vehicular movements in school areas.

11.22 Horizontal Separation Systems. Aside from the typical sidewalk system in suburban or outlying areas previously discussed in "Integrated Systems," horizontal separation embraces the concept of separating pedestrians and vehicles in the same plane. This generally constitutes designation of certain areas for exclusive use by pedestrians. Some of the alternatives for horizontal separation are as follows:

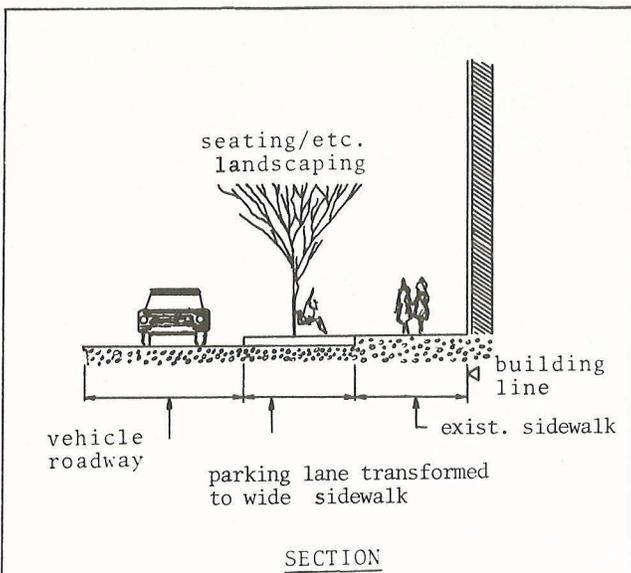
11.22.1 Sidewalk Widening.

- Reduction in street width. Sidewalks in downtown areas may be widened by the elimination of parking and the utilization of this space for sidewalks, as illustrated in Figure 11.1. Such projects can range in magnitude from simply the clinical treatment of reducing the street width, to serpentine treatment with variable widths to facilitate mid-block passenger loading and intersection turn lanes, to the placement of plantings and other decorative treatments to serve as a buffer to traffic. Widening in this manner reduces the confusion, and improves the safety and appearance of the street caused by the congestion resulting from curb parking. The advantages and disadvantages of sidewalk widening are listed in Figure 11.1.

- Arcade Setbacks. In new construction, or where old construction is being remodeled, the building can be recessed to create additional pedestrian space as shown in Figure 11.2. This provides the advantage of sidewalk widening while maintaining street width. It also provides partial cover from the elements. The advantages and disadvantages of arcade set backs are presented in Figure 11.2.

11.22.2 Partial malls. According to most references, it is difficult to distinguish between the high-quality sidewalk widening project and the partial mall. Perhaps this differentiation should be on the basis of traffic restrictions. For example, Nicollet Mall in Minneapolis limits the vehicular intrusion to buses, taxicabs and emergency vehicles. Whereas, the street was at one time a 4-lane street, it is now limited to two lanes. Cross street traffic on the various intersecting streets is not restricted, but the elimination of turns at the intersections greatly improves pedestrian operations.

11.22.3 Full Malls. Full malls are typified by the exclusion of all vehicular traffic except emergency vehicles. A schematic illustration of the full mall, along with the advantages and disadvantages, are presented in Figure 11.3. They provide the opportunity for a full aesthetic treatment which may serve as a stimulus for the urban area. Development is generally funded substantially by the business sector. In



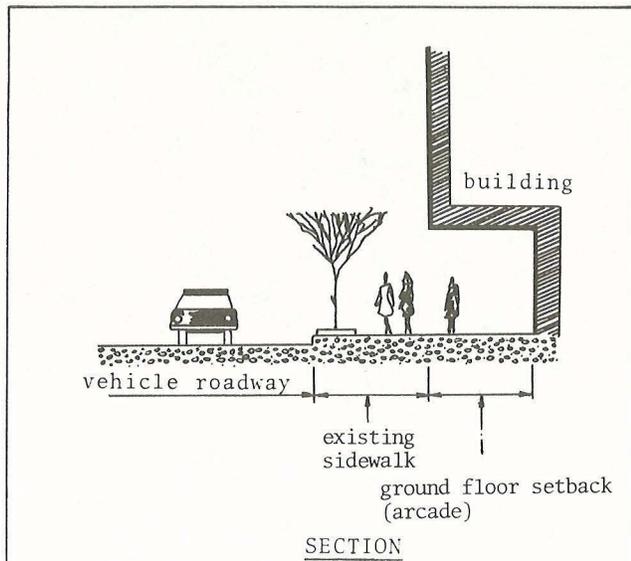
ADVANTAGES

- Increased sidewalk space relieves pedestrian congestion in areas of high volume
- Additional buffer zone reduces potential for conflict and accident
- Annoyance of noise and fumes reduced
- Visual obstruction of parked autos eliminated
- Increases space for pedestrian amenities

DISADVANTAGES

- Reduces width of street available to vehicle
- Increases vehicle congestion on surrounding streets
- Does not solve the problem of conflict at intersections
- Pedestrian exposure to weather is not affected

Figure 11.1. Advantages and Disadvantages of Sidewalk Widening



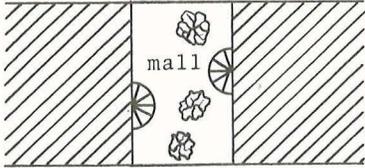
ADVANTAGES

- Relief of pedestrian congestion
- Buffer zone reduces potential for conflict and accident
- Reduced annoyance from fumes and noise
- Increased space for pedestrian amenities
- Some shelter from sun and inclement weather
- Does not reduce vehicle space

DISADVANTAGES

- Does not solve the problem of conflict at intersections
- Depends on cooperation of builders, developers and other private interests
- Reduces store frontage and retail sales space

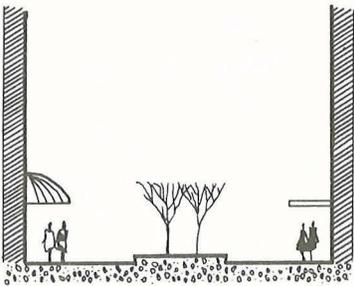
Figure 11.2. Arcade Setbacks



FULL MALLS



PLAN



FULL MALL (URBAN STREET)

SECTION

ADVANTAGES

- Eliminates conflict within mall area
- May be integrated with public transit
- Allows use of people-movers, jitneys, etc.
- Can be developed in stages
- Allows a wide range of communal activities (art fairs, craft shows, entertainment, etc.)
- Can integrate with existing parks, plazas, etc. to create "system" of urban open space
- Stimulates retail activity
- Provides freedom from noise, fumes, and usual obstruction of vehicles
- Eliminates on-street servicing of stores

DISADVANTAGES

- High development, operating and maintenance costs
- Requires comprehensive preplanning
- Increases traffic volumes on surrounding streets
- Depends on total cooperation of property owners and other retail interests
- Acts to reduce retail activity on nearby streets
- Creates legal problems with property lines, etc.
- May require extensive utility upgrading

Figure 11.3. Full Malls (Urban Streets)

the application of the full mall, the major concern of the transportation manager is the integration of the mall with the remainder of the transportation system. Transit, vehicular movement and parking are necessary for the support of the pedestrian system.

11.22.4 Auto-Free Zones. The auto-free zone is principally an extension of the full mall concept where automobile traffic is restricted to give pedestrians exclusive use of an area comprised of multiple street segments. The auto-free zone has the greatest impact on vehicular travel because it concentrates movement, access and parking on the periphery of the area. Because of the problems encountered in servicing the area, it is generally realistic to permit the operation of buses, emergency vehicles, and service vehicles in the auto-free zone. In this respect, it is quite similar to the Nicollet Mall in Minneapolis.

To the transportation manager, it is essential that the consequences of a major change in transportation operations be considered in relation to the benefits to be derived, and that a satisfactory balance be attained.

11.22.5 Displaced Grids. A displaced grid is typically the conversion of alleys to separated horizontal pedestrian facilities, as shown in Figure 11.4. However, they may be incorporated into the re-development of large areas of a CBD. The conversion of alleys to pedestrian facilities generally require extensive modification of existing structures, may create security problems, and displace service access to businesses. Other advantages and disadvantages are presented in Figure 11.4.

11.23 Vertical Separation Systems. Perhaps the ultimate in pedestrian systems, particularly in the high-density areas is the vertical separation concept. Like the freeway, the capacity, safety and operational difficulties due to conflicts are eliminated. Both underground and elevated systems have been implemented throughout the world.

11.23.1 Underground Systems. These systems are often used when there is a need to integrate the pedestrian system with an existing subterranean system such as a subway. The advantages and disadvantages of such a system are outlined in Figure 11.5.

11.23.2 Elevated Systems. Elevated systems are those in which pedestrian movement is accommodated above the level of vehicular movement. The advantages and disadvantages of elevated systems are outlined in Figure 11.6. Perhaps the most publicized of elevated systems is the midblock elevated skyway in Minneapolis. For the purpose of definition, there are five different types of elevated skyway elements. These are:

- Independent
- Independent - flanking
- Integral - flanking
- Integral
- Interior

Illustrations and descriptions of the five types of elevated elements are presented in "A Comparison of Costs and Benefits of Facilities for Pedestrians", Report No. FHWA-RD-75-7, published by the National Technical Information Service, Springfield, Virginia 22151.

11.3 PEDESTRIAN FACILITY COSTS

A major factor in the consideration of the various alternative pedestrian systems is the costs and related benefits. A treatment of the subject in this course is highly impractical. For a detailed treatment of these points, the reader is referred to the report cited in section 11.23.2 above.

11.4 MANAGEMENT GUIDELINES FOR PEDESTRIAN SYSTEMS

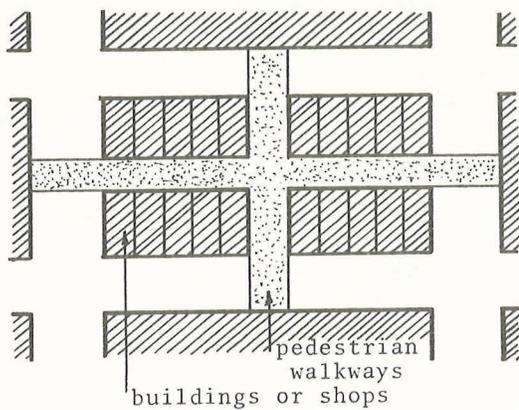
Formulating an orderly process of managing the pedestrian system as an important element of the total urban transportation system is essential. The following guidelines are suggested as an approach to giving the pedestrian system fair consideration.

- Formulate Pedestrian Safety Committee. Like the Traffic Safety Committee, the Pedestrian Safety Committee should be composed of city officials, civic organization representatives and citizens. This committee should serve as an advisory group and a communication element in dealing with urban pedestrian safety problems. Representation could include:

1. Engineering and/or public works
2. Enforcement
3. Education
4. CBD Association
5. Chamber of Commerce
6. Citizens

- Establish Procedures for Identifying Existing and Potential Problems. This would involve the Pedestrian Safety Committee, but should extend far beyond the activities of the committee. Pedestrian studies and surveys should be a significant activity of the transportation engineering group.

- Establish a CBD Pedestrian Plan. A CBD pedestrian plan should be developed jointly by city officials and the business sector in the central business area. This plan should be based on a thorough analysis of transportation needs, facilities and resources of the area.



PLAN

ADVANTAGES

- Eliminates potential for conflict associated with parallel grid
- Facilitates servicing of retail activities with backs to street
- Gives pedestrian direct access to both sides of walkway
- Provides freedom from noise, fumes and visual obstruction of vehicles
- Relieves vehicle congestion at intersection for turning movements
- Mid-block pedestrian crossings eliminate conflicts with turning vehicles and simplify driver attention requirement
- Arcade treatment can provide shelter

DISADVANTAGES

- May require mid-block crossing signals in addition to those at existing street intersections
- Creates unsightly facade along street (back of shops)
- Encourages additional points of conflict, possibly unexpected by drivers, when mid-block crossings are not signaled
- Requires extensive remodeling when incorporated into existing buildings

Figure 11.4. Horizontally Displaced Grids

ADVANTAGES

- Separates pedestrian movement from vehicular movement
- Provides built-in protection from sun and inclement weather
- Does not have to follow traditional parallel grid pattern
- Does not visually or physically obstruct the urban landscape
- Can be built in increments
- Particularly applicable to new construction
- Can be linked directly to existing underground systems
- Provide direct linkage between major activity centers
- Improves vehicular circulation at grade

DISADVANTAGES

- Extremely expensive to construct
- Require change-in-grade and numerous entry points
- Difficult to link new and old buildings
- Orientation and coherence are adversely affected due to loss of visual contact with city
- Artificially created environment
- High potential for crime
- Emergency servicing is restricted

Figure 11.5. Advantages and Disadvantages of Below-Grade Systems

ADVANTAGES

- Separates pedestrian movement from vehicular movement
- Can provide more direct, convenient paths for pedestrians
- Provide elevated visual vantage point
- Provide direct linkage of major activity centers
- Can be built in increments and expanded into comprehensive system
- Particularly applicable to new construction
- May utilize public rights-of-way linking and/or passing through existing buildings
- Allows more compact and efficient arrangement of retailing space
- Improves at-grade vehicular circulation
- Provides cover for at-grade pedestrian movement

DISADVANTAGES

- Expensive to construct
- Requires change-in-grade and numerous entry points
- Difficult and expensive to provide access into existing development
- Could diminish retail activity at the street level
- Coordination of property owners may be difficult to achieve
- Elevated elements form areas at-grade that present security problems
- Difficult to coordinate to at-grade and below-grade transit systems
- Creates potential danger of falling objects if not totally enclosed
- Adds to the already cluttered cityscape
- Difficult to service for emergency, fire, security, etc.

Figure 11.6. Advantages and Disadvantages of Above-Grade Systems

- Integrate Pedestrian Provisions in Sub-division Regulations and Street Design Standards.
- Integrate Pedestrian Provisions in Traffic Operations Measures.
- Initiate Pedestrian Education and Enforcement Programs.

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CHAPTER 12

ALTERNATIVES FOR IMPROVING TRAFFIC OPERATIONS

SESSION OBJECTIVES:

1. *To make the transportation manager aware of the need for better utilization of existing facilities;*
2. *To review, from a management point of view, the alternatives for increasing the capacity and efficiency of urban traffic facilities;*
3. *To identify the essential considerations for management decisions related to low capital traffic facility improvements.*

12.1 INTRODUCTION

Safe and efficient movement of persons and goods has always been a fundamental objective in providing a street and highway network. It is recognized, however, that operational requirements have changed substantially over the years as our street and highway systems have developed and, as a result, many parts of the system have become obsolete. In order to achieve maximum efficiency from such a street and highway system, the system must be constantly reviewed to identify operational problems, and preferably low-capital improvement alternatives must be implemented to correct these operational problems.

A guide to dealing with the operational efficiency on the existing street and highway network is the publication, "Traffic Reviews for Operational Efficiency", by the Federal Highway Administration, published in 1973. This guide defines an operational review as an organized and continuing program of repetitive field observations and inspections of traffic facilities in order to detect inefficient and erratic traffic operations which may be caused by deficiencies in geometric design features, traffic control devices or other related factors.

This session presents some of the alternatives that may be implemented to improve the operational efficiency and capacity of existing street systems. For the convenience of presentation, they categorized into "Design Alternatives" those alternatives which relate primarily to geometric or physical changes to the facility, and "Operational Alternatives" those which relate to traffic control devices and regulatory measures.

12.2 DESIGN ALTERNATIVES

12.21 Intersection Improvements. We have recognized through the years that the intersection is the critical element in the street system that limits the capacity. This is due to the fact that street space must be shared with traffic on the cross street. There are a number of improvements of a design nature that can be made to improve the overall capability of the street to handle traffic. The major categories of these improvements are discussed below.

12.21.1 Correcting Offsets. Many streets exist today with offsets in major arterials due to the haphazard development of land. Because adjacent subdivisions were not planned to coordinate, the streets failed to match precisely. Such offsets are generally quite costly to correct, but they are even more costly to operate. Every effort should be made to achieve good alignment of the streets through the intersection and to incorporate auxiliary lanes wherever possible. This problem was typical of the main thrust of the TOPICS program, and should be continued in TOPICS type projects within the current framework of federal funding for urban improvements.

12.21.2 Addition of Left-Turn and Right-Turn Lanes. Perhaps the greatest single improvement to an arterial intersection is the addition of left-turn and right-turn lanes. Left-turn lanes can have the effect of increasing the capacity of an intersection by as much as one lane on each approach. Such would be the case where left-turn movements combined with near capacity operations in both directions occupy the inside lane throughout virtually all the green signal phase.

The obvious advantage of left-turn lanes is the segregation of traffic flows. When auxiliary lanes are provided, through traffic is not delayed by vehicles waiting to turn. Of course, experience has demonstrated certain safety benefits; any reduction of the occurrence of stopped vehicles in a through lane reduces the speed differential and improves safety.

Another advantage of the left-turn lane is the improved sight distance. Where left-turns are made without an exclusive signal indication, the driver waiting to turn has a better view of opposing traffic.

Left-turn lanes may be implemented as a part

of the implementation of a median on an arterial or they may be introduced as channelization at an intersection, dependent upon the local circumstances. In either case certain minimum design standards relating to lane width should be adhered to wherever practicable. To maintain consistent lane width through the intersection, additional useable street width must be taken from the median, removal of parking, or street widening. Many times the latter alternative is the only one available. Since widening in developed areas is prohibitive from the cost standpoint, consideration may be given to relaxed design standards in the vicinity of the intersection. Experience has shown that narrower lanes are acceptable in the vicinity of the intersection. In the publication, "A Survey of Urban Arterial Design Standards" by APWA, it is reported that turn lanes vary from 9 to 12 feet with the 10-foot lane the most common. Reduced lane widths within the intersection area may tend to reduce speed (a desirable trait) and slightly reduce capacity, but the capacity increase, due to the left-turn lane inclusion, will offset the loss many-fold.

Safety improvements as a result of adding left-turn lanes are fairly significant. Again, referring to the Survey of Urban Arterial Design Standards, a study in Denver reported a 6% decrease in left-turn accidents, a 52% decrease in rear-end accidents and a 28% decrease in injury accidents and total accidents. A similar study in Los Angeles showed a 38% reduction in the number of injury accidents.

To this point, consideration has been given primarily to the benefits of adding left-turn lanes. From a capacity and safety standpoint the left-turn lane is deserving of much greater emphasis. However, the addition of a right-turn lane can yield considerable benefits. Where space is available, and where there is a substantial right-turn volume, the right-turn lane increases the availability of through traffic. Also, the capacity reduction effects of vehicles slowing to turn and the delay effects due to pedestrians are eliminated as far as through traffic is concerned. The prevalent use of right-turn-on-red and the possibilities of moving right-turns on non-conflicting phases greatly enhance the capacity of the intersection.

12.21.3 Intersection Widening. Widening of the intersection can increase the capacity of the intersection and at least approach a balance with the traffic-handling capability of the arterial street at mid-block locations. As discussed previously, the effects of widening may be achieved by removal of parking or rearranging the movements to provide an additional lane for left-turn lanes. On primary arterials where space is not available, and where it would be unde-

sirable to relax design standards, widening of the intersection may be a feasible alternative. Simply widening to accommodate left- and right-turn lanes can increase the capacity of the intersection as much as 25%. At major intersections where there is a high-volume left-turn, a significant capacity increase can be achieved by providing dual left-turn lanes. The improvement in capacity is variable dependent upon the left-turn demand. As an illustration of the benefits, consider a single left-turn lane on a 6-lane arterial that requires 20 seconds of green time per cycle. By providing a dual left-turn lane the green time could be shortened to 12 seconds. The 8 second time savings could result in handling 24 more vehicles per cycle on the 6 through lanes.

An added right-turn lane may serve as a bus stop with a minimum of interference to through traffic. However, a bus stop on the far side of the intersection in a widened section would constitute even less interference with vehicular movement in the intersection.

12.22 Mid-block Improvements.

12.22.1 Access to Property. In general, operational problems at mid-block locations relate to lack of or improper control of access. Too many driveways, poor driveway design and the lack of acceleration - deceleration lanes invariably reduce the quality of traffic flow and safety on the facility. On such streets, these conditions generally exist in the vicinity of the intersections and result in reduced capacity.

The most critical problem with mid-block access is the left-turn maneuver into a driveway, when such a maneuver is made from the inside through lane. One obvious correction is the introduction of a barrier type median that prohibits the mid-block left-turn. However, this generally is not a practical solution where access has already been granted. To say the least, it is politically unpopular. On the other hand, barrier medians should be employed in the development of new arterials where land use has not yet developed. When used in this manner, the land use will be forced to develop according to another access form. When barrier medians are used, and direct access to land is permitted, consideration should be given to the circulatory effects of gaining access to the land use. U-turns at the intersection are most impractical. Access by "circling the block" can be provided by the proper street layout. The most desirable, however, is to encourage access from a side street after turning left at an intersection.

Where right-turns into driveways are permitted, one-way angle drives are preferred.

NCHRP Report 91 provides recommended design standards for driveways that will minimize the effects on traffic operation.

Where there is existing development without access control, many cities have found painted medians or two-way left-turn lanes to be very effective in improving the quality of traffic flow, safety and capacity. The success of painted medians is dependent upon the local or state laws pertaining to crossing painted medians, and the degree to which they are enforced. In either case the operational concept is the same - provide a space where turning vehicles may pull out of the through lanes and wait for an opportunity to turn.

12.22.2 Two-Way Left Turn Lanes. The two-way left-turn lane is considered superior to the painted median channelization because it removes the confusion that may arise as to whether or not turns are permissible. The Manual on Uniform Traffic Control Devices now includes standard markings and signs for two-way left-turn lanes, and they are used extensively throughout the country.

The safety benefits of the two-way left-turn lanes are documented, and the improvements in quality of flow are obvious. Some have advanced the idea that they increase the capacity of intersections by reducing the number of left-turns to be accommodated at the intersection. Obviously, if the turns are permitted at mid-block, those that would have otherwise been routed through the intersection to gain access have been eliminated.

12.23 Designing for Bus Operations. One of the most attractive methods of improving urban transportation is the utilization of high-occupancy public transit vehicles that will operate within the existing street system. Many of these (carpools, vanpools, taxis, etc.) have the same operating characteristics as the private passenger car and, thus, blend into the system. The local bus, however, is drastically different in operational characteristics, and, hence, there are several design-oriented alternatives available to the transportation manager that will improve its effectiveness.

12.23.1 Intersection Design for Buses. Buses have critical maneuvering characteristics and should be considered in the re-design of intersections. AASHTO has now established a new design vehicle, the BUS designation, which has a 25-foot wheel base. The dimensions of the unit are given in the 1973 edition of the red book, A Policy on Design of Urban Highways and Arterial Streets, and these should be utilized to assure efficient accommodation of bus services on the street system.

The experimental articulated buses are de-

signed to carry a large number of passengers and to negotiate normal street geometry. No doubt these vehicles will encounter problems with some of the geometric features and, therefore, the transportation manager should seek to accommodate these vehicles through design guidelines wherever practicable.

12.23.2 Bus Loading Facilities. One of the major differences in the character of bus operations on the street system is the frequent number of stops required through normal service. There are a number of alternatives whereby the transportation manager may provide good bus operations with a minimum of interference with other vehicles using the system.

In downtown areas, the lane arrangements are sometimes established to provide exclusive use of the curb lanes for bus operations, including the loading and unloading of passengers. To insure compliance by auto drivers, the bus lanes are sometimes marked physically with pylons and are designated contra-flow - counter to the direction of other traffic.

On primary arterials, it may be desirable to construct special bus turn-outs or loading bays. From an operations viewpoint, these should be located mid-block so as not to interfere with intersection operation. If an intersection loading point is more desirable from the bus service standpoint, then a far-side location relative to the intersection is preferred, particularly where a bay is to be provided. Design standards for bus loading facilities are included in the 1973 edition of the "Redbook."

12.23.3 Shelters. Shelters at bus loading points are a "must" in areas of extreme climates, and may enhance the bus ridership in practically any area. There are certain features of the shelter that should be designed to fit the peak demand. An inadequate-sized shelter is perhaps a detriment rather than an asset. Shelters should provide visual security - that is, persons in the shelter should be visible from all directions to aid in deterring criminal acts to the person. Shelters that are commonly used have plastic panels that protect waiting passengers from the wind and rain, yet provide visibility. Some are heated - a feature that, perhaps, will be scrutinized seriously as energy concerns and costs increase.

12.3 OPERATIONAL ALTERNATIVES

Operational alternatives to increase the efficiency of arterial streets include those which can be accomplished without additional right-of-way or reconstruction of the facility. Each can be fully implemented within the existing curb lines using a combination of relatively low cost signs, pavement mark-

ing, and signalization improvements. Operational alternatives can be classified into types of improvements. These are:

Changes in the Major Flow Pattern

- one-way streets
- reversible flow
- unbalanced flow
- two-way left turn lanes

Changing of Intersection Operational Patterns

- prohibited left turn
- right-turn-on-red
- relocation of bus stops
- protected left turns

Traffic Signal Modernization

Traffic Signal Coordination

Computer Control of Traffic Signals. This list is not complete, but it includes the more common operational changes which can be used to increase arterial street capacity. For purposes of discussion, the first two of these operational alternatives have been regrouped into those from which large capacity increases (i.e., 25% increase or greater) can be expected and those from which smaller capacity increases should be expected.

12.4 LARGE CAPACITY INCREASE ALTERNATIVES

12.41 Expected Benefits. The operational alternatives which can be expected to result in a capacity increase of twenty-five percent or more are a) one-way operation; b) reversible flow; and c) the prohibition of left turns at intersections where no left turn lane is provided. The capacity increase range reported for each of these three alternatives is presented in Table 12.1.

TABLE 12.1 Range of Capacity Increases - Large Capacity Increase Alternatives		
Alternative	Range of Capacity Increase Reported	Source
One-way operation	20-50%	Bruce(1)
Reversible flow	20-50%	LePlante(3)
Left turn prohibition	14-40%	Shoaf(5)

Any improvement which substantially increases vehicular capacity also reduces the accident potential. This fact is illustrated by the reported accident reduction presented in Table 12.2.

A capacity increase of this magnitude also is reflected in a reduction in travel time through a system which includes these improvements. The effects in system travel time reported for each of the three large capacity increase alternatives are presented in Table 12.3.

TABLE 12.2. Range of Reported Accident Reduction - Large Capacity Increase Alternatives		
Alternatives	Range of Accident Reduction Reported	Source
One-way operation	0-60%	Mayer(4)
Reversible Flow	0-30%	DeRose(2), LaPlante(3)
Left turn Prohibition*	40-70%	Shoaf(5)

* Assumes no separate turn lane

TABLE 12.3. Travel Time Reduction Reported - Large Capacity Increase Alternatives			
Alternative	Range of Accident Reduction Reported	Average	Source
One-way operation	20-40%	30%	Bruce(1)
Reversible flow	20-50%	30%	LaPlante(3)
Left turn prohibition	35-100%	50%	Shoaf(5)

A reduction in stopped time has also been observed. The results are presented in Table 12.4.

12.42 Cost of Implementation. The cost of implementing any of the large capacity increase alternatives depends on local site conditions. The range of cost which might be expected for each of the alternatives (on a 1975 cost base) is presented in Figure 12.5.

TABLE 12.4. Reported Stopped Time Reduction - Large Capacity Increase Alternatives

Alternative	Range of Stopped Time Reduction Reported	Average	Source
One-way operation	60-85%	70%	Bruce(1)
Reversible flow	30-70%	45%	LaPlante(3)
Left turn prohibition	50-90%	70%	Shoaf(50)

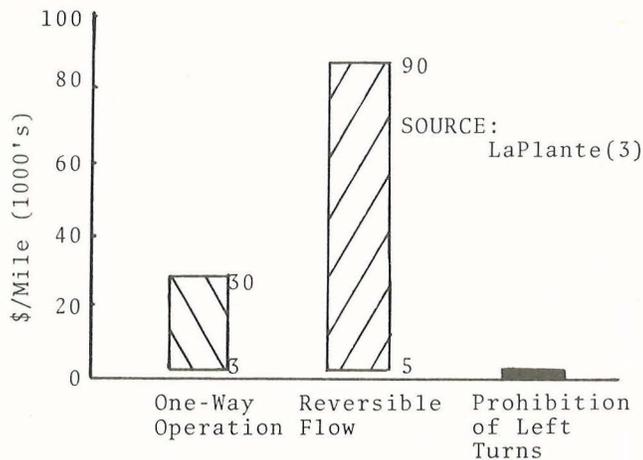


FIGURE 12.1. Estimated Implementation Cost - Large Capacity Increase Alternatives

The largest costs associated with reversible flow are in instances where overhead signalization is deemed necessary for satisfactory operation. Overhead signal installations on a rigid structure (as opposed to a span wire mounting system) can easily run \$15-\$20,000 per installation. To be effective these units must be located at about one-quarter mile intervals. The signal units are the major part of the cost of the system. The plastic cones which are manually placed have been used in lieu of signalization; however, the cost has generally proven to be excessive as a permanent operation.

12.43 Political, Social and Economic Consequences. The public reaction to any change in the traffic flow pattern must always be considered very carefully. For example, merchants often fear that one-way street systems will substantially reduce their business. Experience in many cities indicates that this is not the case. Business income is usually increased due to a greater amount of accessibility provided potential customers. Transit operations may be adversely affected by one-way operation. While transit operation will benefit from reduced congestion, the added walking distance may discourage more patrons than are gained from those living near the other half of the pair. The frequency of use by out-of-town drivers, as well as the availability of a suitable site for the transition back to two-way operation, should also be considered.

Reversible flow, except in the rare case of total reversal, does not generally produce the adverse criticism which is characteristic of one-way operation. This is primarily due to the fact that reversible flow operation matches the normal pattern of the majority of the population. Prohibition of left turns is the reverse; however, being directly contrary to normal behavior usually does result in adverse reaction and frequently heavy political pressure.

12.5 SMALL CAPACITY INCREASE ALTERNATIVES (less than 25 percent)

A capacity increase of less than 25 percent has been termed a small capacity increase. There is no intent to imply insignificant increases but rather increases of smaller magnitude than those previously described. Included in this category are the following improvement alternatives:

- Unbalanced Flow
- Right-Turn-on-Red
- Two-way Left Turn Lane
- Relocation of Bus Stops
- Provision for Protected Left Turns

The magnitude of the capacity increases to be expected is presented in Table 15.5.

The accident reductions which can be expected from the small capacity increase alternatives are tabulated on the following page.

TABLE 12.5. Expected Capacity Increase - Small Capacity Increase Alternatives

Alternative	Range of Capacity Increases	Estimate Average	Source
Unbalanced Flow	5-15%	8%	Estimated
R-T-O-R	2-35%	18%	Ray(6)
2-Way Left Turn Lane	8-20%	10%	Sawhill(7)
Relocation of Bus Stops	0-10%	3%	Estimated
Protected Left Turns	Highly Variable - May Be Negative		

The accident reduction benefits of the small capacity increase alternatives are generally lower than those associated with the large capacity increase alternatives. The provision of protected left turns is the exception. The 40% expected reduction in left turning accidents approaches the reductions achieved from the large capacity increase alternatives.

Travel time reductions associated with the small capacity increase alternatives have not been as detailed as for the large capacity increase alternatives. Based on the limited data available, an estimate of the trip time reduction which might be expected has been made. These estimates are presented in Table 12.7.

The unbalanced flow estimates are based primarily on the similarities of unbalanced flow and one-way operation where the provision of multilane operation in one direction provides opportunities for faster moving vehicles to pass the slower ones. The two-way left turn lane has its greatest advantage in removing vehicles waiting to turn left from the through traffic lane. Since the left turn into roadside commercial areas, the predominant type of activity served by the two-way turn lane, is rarely made during the peak periods, the reduction in trip time is probably rather small, if measurable.

The relocation of bus stops in the CBD can significantly reduce the delay to turning vehicles. On arterial streets outside the CBD, the frequency of local transit buses rarely produces a significant reduction in travel time, hence, the "negligible" estimate.

The provision of protected left turns may reduce the length of the left turn queue and thus reduce the travel time to the through stream of traffic. It is not expected that the provision of a protected left turn would decrease the travel time by more than 10 percent.

The implementation costs of the small capacity increase alternatives have been estimated based on 1975 cost data. These estimates are presented in Table 12.8.

TABLE 12.6. Accident Reduction Expected - Small Capacity Increase Alternatives

Alternative	Range of Accident Reduction	Estimated Average	Source
Unbalanced Flow	0-10%	4%	Estimated
R-T-O-R	0-12%	3%	Ray(6)
2-Way Left Turn Lane	10-30%	20%*	Sawhill(7)
Bus Stop Relocation	0-3%	Negligible	Estimated
Protected Left Turn	0-60%	40%	Malo(8)

* Based on a reduction in left turns at the intersections and rear end collisions in the left lane midblock.

TABLE 12.7. Estimated Trip Time Reduction - Small Capacity Increase Alternatives

Alternative	Estimated Trip Time Reduction
Unbalanced Flow	20-50%
R-T-O-R	7-10% Ray(6)
2-Way Left Turn Lane	0-10%
Bus Stop Relocation	Negligible
Protected Left Turns	0-10%

TABLE 12.8. Estimated Cost of Implementation - Small Capacity Increase Alternatives

Alternative	Implementation Cost Estimate
Unbalanced Flow	\$600 per Mile
R-T-O-R	\$300 per Intersection
2-Way Left Turn Lane	\$2000 per Mile

TABLE 12.8 (Continued)

Alternative	Implementation Cost Estimate
Bus Stop Relocation	Negligible
Protected Left Turn	\$500-\$1000 per Intersection

12.6 SIGNAL MODERNIZATION

One of the reasons for continued accident problems at intersections in urban areas is competition for driver attention. The problem becomes most acute in commercial areas where advertising signs and store window displays are designed to attract the eye. The situation becomes particularly bad at wide intersections having signals post-mounted on the corner and out of the driver's zone of sharp vision. Therefore, it appears that if the signal can be made more competitive visually, the number of traffic accidents should be reduced (9).

The Department of Traffic for Los Angeles in a continuing program to improve the visibility of traffic signals along its arterial streets upgrades every signalized intersection approach of two or more lanes to the following standards:

- Fifteen-foot long mast arms and 12-inch lens signal heads for each direction along the arterial street;
- Mast arms and 12" lens signal heads for each cross street approach of two lanes wide or wider;
- Relocation of post-mounted signals as close to the traveled way as practicable;
- Installation of pedestrian signals where warranted; and
- Installation of high intensity luminaires (9).

TABLE 12.9. Signal Modernization Effects

Accident Type	Signalized Intersections		Unsignalized Intersections	
	% Change	Significance	% Change	Significance
Right Angle	-48%	Yes	+38%	Yes
Rear-End	-49	Yes	-22	No
Left Turn	- 7	No	0	No
Pedestrian	-19	No	+50	No
Miscellaneous	+84	Yes	+226	Yes

The only significant reductions were in right-angle and rear-end accidents. at signalized intersections, the categories upon which improved signal visibility could be expected to have the greatest effect. The number of miscellaneous accidents would not be expected to be affected by improved visibility. Looking at the increase in the number of right-angle accidents at unsignalized intersections and comparing it with the decrease at signalized intersections, the effectiveness of improved visibility can be further demonstrated (9).

Based on the accident history comparison for the 68 intersections which had improved signal visibility, it can be concluded that this type of improvement will have a significant effect in reducing the most predominant type of accidents at urban signalized intersections and will, therefore, have a high payoff in relation to the relatively low cost of improvement (9).

The Department of Traffic for New York City had similar results from their program for improved visibility of traffic signals. In late 1966 and early 1967, the city improved 25 intersections in Manhattan by removing obsolete signal heads and supports and installing three-level WALK-DON'T WALK signs for pedestrians. The results were a reduction in injury accidents by 56.6% and total accidents by 25.3% (10).

In 1967, Detroit also had an extensive program of signal modernization. Improvements were made by installing two overhead signals on major routes and at least one signal facing each approach on minor streets. The accident rate on the average of the 20 improved intersections decreased by 50%. Right-angle collisions decreased a whopping 75%.

The degree to which modernization may reduce accidents depends on the severity of accidents and traffic patterns at the existing intersections. In general, modernization which provides better visibility, such as farside mounting, is most effective (11).

The benefits of signal modernization reported for urban areas may not be as significant for rural intersections. A recent study in West Virginia indicated no significant decrease in accidents after upgrading of the signalization to conform to the standards of the Manual on Uniform Traffic Control Devices.

12.7 BENEFITS OF COORDINATION

The benefits of signal coordination are two-fold. First, effective coordination can reduce the number of stops at the signals in the system and reduce the potential for rear-end collisions. Secondly, by reducing the

number of stops, signal coordination can reduce vehicular delay. While the travel time is reduced very slightly and speed increased slightly, the number of involuntary stops is reduced by 40 percent and accident experience by some 10 percent. Similar studies have indicated that a 40 percent reduction in the number of congested cycles, a 2-3 percent increase in capacity, a 10 percent reduction in density, and a 5 percent reduction in the queue length can be expected from effective coordination of the signals.

Cooper (13) evaluated the effects on travel time for alternate, simultaneous, and flexible progressive systems. Figure 15.2 illustrates that there is little difference in the alternative and simultaneous systems, whereas the flexible progressive system offered a substantial advantage in reduced travel time (33 percent at low volumes and 26 percent at higher volumes).

From these research findings, there can be little doubt that coordination of signalized intersections offers substantial benefits to the motoring public and should be considered whenever a series of signals is located along one continuous route.

12.8 COMPUTER CONTROL OF TRAFFIC SIGNAL SYSTEMS

12.81 Current Use of Digital Computers.

The use of a digital computer to control traffic signal indications is currently in use in about 40 cities at the present time. Another 75 such projects are now in various stages of development, and an additional 30 to 40 systems have been proposed (15). This magnitude of application suggests that substantial benefits can be obtained using digital computer control as the relatively high cost of such a system is well known.

12.82 Types of Computer Control. Three basic types of computer control are currently being used.

- Computer Supervision of Local Controllers - The use of a local intersection controller driven by commands from the computer is common. The local control provides for signal operation during the periods of computer down time.
- Multi-Level Computer System - The use of a multi-level computer system consisting of a micro-computer with preprocessing capability at the local intersection to control the signal indications and process the various input data and the supervisory computer which accepts preprocessed information, processes these data through the decision stage and issues commands back to the mini-computer to execute area control strategies.

- Direct Computer Control - The use of direct control of signal indications by a central computer with a standby controller for emergencies at the local intersection.

The majority of all existing installations are of the first type. This is primarily due to the lower initial cost and the necessity for standby controller in the event of a computer system malfunction. The use of a mini-computer provides for more flexibility in operating the intersection and reduces the number of communications links necessary to handle the input data from field sensors.

12.83 Benefits of Computer Control. The flexibility offered by digital computer control to adapt to wide variation in flow (particularly special events), a more complete monitoring of the control hardware and a better analysis of traffic data when combined with the public relations advantage of being able to say "We have the most sophisticated traffic control system available," may justify the decision to go to computer control.

The objective of providing more efficient operation using highly sophisticated forms of traffic responsive control is often questionable from a cost-effectiveness point of view. Tarnoff (16) indicates that with highly responsive computer control, a reduction in delay of 4 to 5 percent is all that can be expected when compared to systems controlled by conventional control equipment which is being efficiently operated. This decrease in travel time at approximately three times the cost per intersection does not appear to be justified. However, on the basis of time saved, a travel time decrease of 2 to 3 percent would offset the cost of the computer system over its expected life span (17).

12.84 Cost of Computer Control. The incremental cost of a computer installation over that of a conventional installation to supervise the operation of about 100 intersections would be on the order of 1/4 to 1/2 million dollars. Annual operating and maintenance costs of \$25,000 to \$50,000 annually should be expected. For a more detailed treatment, the reader is referred to reference 18.

12.9 CONCLUDING REMARKS

The preceding material has identified the magnitude of the increase in capacity which can be expected from a number of operational alternatives along with other operational benefits which would probably occur and an estimate of the implementation cost which should be anticipated. Using a knowledge of the demand which is to be satisfied, operational alternatives can be examined and a candidate list of alternatives which offer a magnitude of capacity increase sufficient to meet the demand can be selected.

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CHAPTER 13

FREEWAY OPERATIONS MANAGEMENT

SESSION OBJECTIVES:

1. *To make the transportation manager aware of the general concepts of freeway operations;*
2. *To review the various alternatives of freeway operations management, and the attendant costs and benefits; and*
3. *To identify the essential considerations for management decisions on freeway operations alternatives.*

13.1 WHY FREEWAY CONTROL AND OPERATIONS

The value of freeway control is variable depending on the character of the freeway and the nature of the congestion. In general, however, a controlled freeway may be stabilized at a service volume of around 1800 to 2000 vehicles per hour per lane, whereas, stop-and-go operation will result in service volumes of around 1200 to 1400 vehicles per hour per lane. Thus, the improvement in capacity is substantial. The annual savings in time will more than offset the cost of the control system. In this session the general management concepts are presented.

13.11 Original Concept of a Freeway. The freeway was conceived as a non-stop, high-speed roadway to carry travelers from origin to destination of a trip in a minimum time. As early as 1955, some doubts had been raised regarding the validity of this operating concept. By 1960 serious attempts were underway to reduce the magnitude of congestion on urban freeway systems. It is now rather apparent that control of access during a portion of the day will be required if the urban freeway system is to achieve even a fraction of the intended function.

13.12 The Nature of the Freeway Concept Failure. The breakdown of the freeway concept can be traced to two basic types of incidents.

- Recurring Incidents. Congestion which is routinely expected at predictable locations and time periods. Characteristically this type of incident stems from the demand on the facility exceeding its capacity.
- Non-Recurring Incidents. Congestion resulting from unpredictable events such as accidents, incidents, bad weather, etc. These events result in the capacity of the facility being temporarily reduced to a value less than the demand level. The California Division of Highways reported

that 57 percent of the congestion-producing incidents were of the non-recurring variety.

13.13 Control and Operational Strategies Used to Maintain Intended Freeway Function. The strategies used to protect the function of the freeway system fall into two broad categories.

13.13.1 Recurring Incidents.

- Reduce demand through ramp control.
- Reduce demand through mainline control.

13.13.2 Non-Recurring Incidents.

- Clearing of capacity limiting incident; and
- Demand control during incident duration.

Implementation of these strategies takes on many forms as required to meet local site conditions and legal restraints.

13.2 ELEMENTS OF FREEWAY OPERATION

13.21 Ramp Control (1). The control of access to the freeway at on-ramps is a basic approach to limiting the demand on a congested freeway section. This, in general, takes two forms: 1) Ramp Metering, either on a real time or time-of-day basis; and 2) Ramp closure, either on a short-term, temporary basis, or on a permanent basis.

13.22 Main Line Control. On-freeway control of demand usually involves one of three basic types of controls: 1) Lane closure on either a temporary or permanent basis; 2) Limiting upstream demand through some form of control; and 3) Speed control to take better advantage of available capacity.

13.23 Corridor Operation. Frequently, when the freeway is congested, a parallel arterial street may have relatively light traffic. This is particularly true in the case for nonrecurring incidents. This fact suggests that simultaneous control and surveillance of both the freeway and parallel arterial street signal systems in the same travel corridor could be used to great advantage. Corridor control includes three basic operations:

- Surveillance of the traffic status of all facilities being controlled;
- Projecting future traffic status of the

facilities;

- Advising the motorist at critical points in the system of the best alternative routing.

Corridor control systems may also include real-time modification of traffic signal displays to optimize the total corridor flow.

13.24 Traffic Surveillance. Surveillance of the traffic status on the roadway being controlled is the only means of determining when non-recurring incidents require modification of the control strategy and what magnitude of modification is necessary. For recurring incident management, surveillance is necessary to determine any changes in the system's operation which would require modification of the control strategy.

13.25 Real-Time Information Systems. While 70 to 80 percent of the benefits of demand control can be achieved on a time-of-day implementation of freeway controls, such systems can not quickly respond to unpredictable incidents. A system of real-time measurement, evaluation, control and driver information feedback is required to fully take advantage of the control system. The driver feedback portion of the real-time control system is termed Real-Time Information Systems.

The provision for real-time information displays increases the cost of system control by a substantial amount. Such systems are, however, viable alternatives on many urban freeway systems where two or more alternative routes are available within a single traffic corridor.

13.3 MANAGING DEMAND THROUGH FREEWAY CONTROL.

13.31 Measuring Demand. The basic flow equation which must be solved is:

$$\text{Density} = \text{Volume/Speed}$$

Thus, these three parameters are the most fundamental ones to measure. Everall (1) discusses the various methods of measuring and displaying these basic parameters as well as a host of other measures which may be beneficial. Pinnell, et al. (2) also discuss these parameters and illustrate their application.

13.32 Surveillance Methods. Methods of visual surveillance of traffic facilities have been examined in detail by Reiss, et al. (3). These data, combined with the experience of the Texas Transportation Institute in electronic surveillance, lead to the following methods being identified and the cost data for each presented.

<u>System</u>	<u>Initial Cost</u>	<u>Annual Costs (10 years)</u>
CCTV (4)	\$400,000	\$80,000
Patrol Vehicles (3)*	\$40,000	\$230,000
Electronic Surveillance --real time (4)	\$700,000	\$80,000
Electronic Surveillance --time of day (4)	\$200,000	\$50,000

* Includes \$35,000 for the renewal of vehicles within 10 years.

Each of these systems must be carefully examined to determine which has the greatest potential for meeting the needs at a particular location.

13.33 Ramp Metering. Ramp metering is perhaps the simplest and the most common approach to regulating demand on an urban freeway. Metering systems can range in complexity from a signal on a single ramp, operated by a time clock, to a series of several ramp signals supervised by a computer on a traffic response basis. Within the context of ramp metering, there are three basic alternatives; ramp closure, fixed metering rates, and traffic responsive metering rates.

13.33.1 Ramp Closure. Ramp closure simply prohibits entry to the freeway at a given ramp during critical hours. This is a severe alteration of traffic operation in a given area, and is generally used to divert short trips near the CBD to the surface street system. Closure may also be used where an area may be served more efficiently at another ramp.

13.33.2 Fixed Metering Rates. The number of opportunities to enter the freeway is controlled on a time-of-day basis using predetermined metering rates. This is the simplest operational scheme for ramp metering and can be expected to yield 70-80 percent of the benefits of a real time control system at about 30 percent of cost.

The planning data required for implementation of a fixed time ramp metering system are:

- O-D Studies of vehicles using the ramps for an accurate prediction of the pattern of traffic diversion
- Before studies:
 - Volumes by time of day
 - Peak and off-peak speed data

- Travel times during peak and off-peak periods
- Demand-capacity analysis of bottlenecks
- Studies of probable effect of diversion on parallel streets
- Cost effectiveness of control to justify controls

Pinnell, et al. (2) cover in great detail the development of specifications for control equipment for isolated ramp control. As a general cost guidance, a figure of \$10,000 to \$12,000 per entrance ramp should be anticipated.

13.33.3 Traffic Responsive (Closed Loop) Ramp Control. In traffic responsive ramp control, the decisions for closure and opening of the ramps, changes in the metering rate, and the time of release of ramp vehicles are based on traffic conditions at the time of control.

• Planning for Traffic Responsive Systems. The planning studies for traffic responsive systems are essentially the same as for fixed time metering systems.

• Traffic Responsive Control System Components.

- A display subsystem
- A vehicle detection subsystem
- A transmission subsystem
- A control subsystem

The transmission and control subsystems are the elements which drastically increase the system cost, although some additional detection equipment is required. It is also these features which provide the real-time control capability. Blumentritt (4) estimates that these two subsystems each cost just about the same amount as the cost for the first two subsystems.

13.34 Main Line Control. The closure of lanes on the freeway has long been used as a basic control strategy. The John Lodge Expressway in Detroit and the Oakland Bay Bridge in California are examples of such systems. Main line control through closing one or more lanes of the freeway to improve the operation on another element of the system has proven to be very successful.

More recently, proposals for main lane demand metering have been made. This concept, if implemented, would place signals on the main lanes at points well upstream from the congested area and meter the flow into the section. This will permit a greater utilization of the ramps downstream and thereby improve the operation of intersecting roadways.

Main line controls have an inherent disadvantage over similar ramp control systems.

Namely, there is no alternative route, and the roadway ahead is relatively clear. These conditions are conducive to a high violation rate, and relatively high level of enforcement will probably be required to make the system operate successfully.

13.35 Corridor Operation. The balancing of the traffic loads among the parallel facilities within the corridor in accordance with the demand/capacity relationship will result in optimum operation. Extending the scope of the control system increases geometrically the information requirements for effective control. While pretimed systems can be effective, the inability to respond to incidents on any one of the facilities limits the potential of the system. Real-time control is necessary to reap the substantial benefits of corridor control systems. Elements of the system - A corridor control system usually contains the following elements:

- Freeway Surveillance System
- Freeway Ramp Control System
- Frontage Road Surveillance System
- Frontage Road Control System
- Arterial Street Surveillance System
- Arterial Street Control System
- On-Freeway Driver Information Systems
- Off-Freeway Driver Information Systems
- A Supervisory Computer System

The complexity of a corridor control system is apparent. A rather sophisticated computer is necessary to monitor the operation and evaluate the rather complex trade-offs involved.

13.4 MANAGING NON-RECURRING INCIDENTS

13.41 The Problem. Freeway control measures have improved the operation and safety of urban freeways, but are limited in their ability to respond to capacity-reducing incidents. These incidents involve more than half of all congestion producing situations as previously noted. Such incidents result in excessive vehicle delays, an increased level of driver frustration and adversely affect the safety of other motorists.

On a typical section of older freeway of about 8 miles in length, an average of 13 incidents per week occurred in one direction only. An accident blocking one lane of a three-lane, one-way roadway reduces the capacity by 50 percent. When two of

the three lanes are blocked, an 80 percent reduction occurs.

The problem then is to identify the existence of an incident, to clear the capacity reducing situation as soon as possible, and to control the system inputs to a level at or below the remaining capacity.

13.42 Incident Detection and Identification.
Methods of detecting capacity-reducing incidents include:

- Patrol Vehicles
- Roadside Call Boxes
- CCTV
- Electronic Surveillance
- Aerial Surveillance

13.42.1 Patrol Vehicles

Advantages:

- Instant classification of incident
- Minimum response time to incidents
- Minimum time to clear incidents
- Can service minor needs immediately (gas, flat tire, etc.)

Disadvantages:

- Cost
- Takes personnel from other duties
- Uses large quantities of fuel

13.42.2 Roadside Call Boxes

Advantages:

- Permit classification of need to a degree
- Identify general area of incident
- Less costly than patrol units

Disadvantages:

- Location of incident not defined
- Limited identification of need
- False calls or driver leaves prior to arrival of help
- Vandalism
- Time delay in responding to incident
- Cost of service difficult to indicate

13.42.3 Closed Circuit Television

Advantages:

- Positive identification of incident
- Immediate classification of incident
- Positive location of incident
- Identification of best approach to incident for emergency vehicles

Disadvantages:

- High initial cost
- Relatively high annual operating costs
- Visual monitoring is boring and, after a few days, major incidents may go undetected for several minutes
- Electronic surveillance backup systems are commonly required to alert monitors to potential problems

13.42.4 Electronic Surveillance.

Advantages:

- Incident detection not dependent on human monitoring
- Effects of incident detected quickly
- Lower cost than other surveillance alternatives

Disadvantages:

- No classification of incident type
- Delay in arrival of emergency equipment
- Vehicle must be dispatched to investigate
- System subject to electronic malfunctions

13.42.5 Aerial Surveillance

Aerial surveillance using both helicopter and fixed wing aircraft have been used. Basically, these are TV systems with an aircraft as the mechanism.

Advantages:

- Large area coverage with minimum equipment
- Better perspective of incident
- Positive incident identification
- Positive location of incident

Disadvantages:

- Costly
- Limited by weather conditions
- Requires visual monitors - boring

13.43 Incident Servicing. One of the most important aspects of servicing freeway incidents is the rapid clearing of the incident in order to restore normal operation. Several methods of providing needed motorist services have been employed including the following ones:

- Courtesy patrols
- Police
- Emergency Services

13.43.1 Courtesy Patrols. The cost-effectiveness of courtesy patrols was examined by Fambro (5). Fambro reports that in one year of courtesy patrol operation on a 24-hour basis, an estimated total of \$477,000 in savings were attributed to the system. Of the total, some \$385,000 was estimated as time savings by motorists by early clearing of the incidents. The cost of the service was \$230,000 which results in a cost/effectiveness ratio of 2.07. Courtesy patrols on high volume urban freeways appear to be highly cost effective.

13.43.2 Police Services. The use of police vehicles to service motorist needs on urban freeways has been successfully utilized. Often the approach is discouraged due to the lack of adequate manpower by the police agencies. Another distinct drawback to this approach is the problem of lack of coverage when emergency calls are being handled. For these reasons, the police units are commonly instructed to provide reasonable assistance to stranded motorists in order to insure the safety of other motorists, but they are not generally assigned to courtesy patrol duty on a routine basis.

13.43.3 Emergency Services. Meeting the emergency service need of freeway drivers can be handled in one of a number of ways. The most basic one is the calling of private businessmen to provide needed services. A careful program must be worked out to insure that private firms will not compete for emergency service business and, at the same time, insure that the motorist will not be overcharged for services actually rendered. This has been accomplished by setting up a rotating call system including all firms providing the needed service in a given area and specifying the amount that can be charged for the services rendered as a result of a call from the police.

When fire and ambulance vehicles must reach an accident scene quickly, travel the wrong

way up the freeway from the next downstream exit ramp is frequently the only practical way to reach the site. When this approach is used, great care must be exercised by the emergency vehicle driver to insure reasonably safe operation in this very unexpected situation.

13.44 Restoring Traffic Service.

13.44.1 Efficient Detection and Identification. The restoring of normal traffic conditions is most directly controlled by the time required to identify the nature of the capacity-reducing incident and getting the needed services. The various surveillance methods are discussed in Section 13.42 above. The transportation manager must place the greatest emphasis on minimizing the response time to incidents.

13.44.2 Accident Investigation Sites. Abnormal incidents on freeway lanes cause hazardous operations, congestion and delay to motorists. The most common ones encountered are accidents and stalled vehicles. The effect of these incidents is illustrated by the data presented in Table 13.1.

TABLE 13.1. Available Capacity During Different Freeway Incident Conditions

<u>Condition</u>	<u>Observed Flow Rate (Veh/Hr)</u>	<u>Reduction in Capacity</u>
Normal	5,560	-
Stall (one lane blocked)	2,880	48%
Non-Injury Accident (one lane blocked)	2,750	49%
Accident (two lanes blocked)	1,150	80%
Accident on Shoulder	4,030	28%

As noted in Table 13.1, the effect of blockage is significantly greater than the actual blockage. These data do not take into account the effects on vehicles traveling in the opposite direction. The effects noted in Table 13.1 remain until the incident is cleared from the motorists are Police investigation of an accident is usually made on the shoulder of the freeway and, therefore, extends the time period during which the upstream motorists are distracted by slow moving vehicles.

One solution to this problem is the use of

sites located in areas not visible to freeway motorists for investigation of the accident. The use of such sites not only improves freeway operation but reduces the hazard to investigating officers and the involved drivers.

In most urban areas, many miles of urban freeways do not have sites specifically prepared for the investigation of accidents. A priority should be established to provide for the installation of accident investigation sites as a service to the motoring public. One site should be identified for each freeway exit ramp. Unused space under elevated structures, on adjacent service roads, or on the local street system can be used. These sites must be known to the police and their function explained to the public.

The cost of implementing accident investigation sites will vary from less than \$100 to several thousand dollars depending on local site conditions. This cost will, however, be almost fully offset by removal of one peak period accident to the site for investigation.

13.44.3 Real-Time Driver Information Systems. Those locations instrumented for closed loop feedback of information to upstream motorists can utilize this capability to divert upstream drivers to alternate routes, thus reducing the demand on the congested section of the freeway. To fully utilize the potential of the urban freeway systems, dynamic information systems must be used.

Real-time control does not necessarily mean instantaneous control. Real-time systems operate on a time-of-day basis, on specific predictable incident basis and on short-term response to specific incidents. The transportation manager must begin to think in terms of dynamic information systems and work toward their implementation and use.

13.5 MANAGEMENT GUIDELINES FOR TRAFFIC CONTROL SYSTEMS

13.51 Manpower Requirements. The basic steps in the development of traffic control systems include:

-), Problem Definition
-), Development of the Traffic System (knowledge Level
-), Design of the System Subelements
-), Constraint Evaluation

The development of complex traffic control systems requires a manpower base which includes many different specialists. Notable in this group are systems engineers and

systems analysts, traffic control specialists, computer technology specialists, and the technical manpower to plan for, install and operate the system. The basic cost of such a team of specialists would approach \$150,000 per year.

13.52 Setting Objectives. Problem definition provides detailed identification of the problem or problems to be solved and the establishment of specific system objectives.

They should evolve from traffic studies and provide a clear definition of the results expected from the system. Functional areas in which objectives should be established include:

Traffic Operations

- Minimize Delay
- Minimize Stops
- Maximize Capacity
- Minimize Accidents
- Others

System Reliability

- Maintainability
- Failure Monitoring
- Fail-Safe Backup Systems

Adaptability

- Traffic Changes
- Physical Changes
- Control System Expansion
- New Control Strategies
- New Control Functions

Implementation

- Phase Implementation
- Traffic Impact
- Implementation Complexity
- Availability Schedules

Flexibility/Special Needs

- Priority Service for Selected Vehicles
- Driver Information Systems
- Surveillance

● Area Wide Control

13.53 Identification of System Alternatives. Control system knowledge is developed through an identification and understanding of the major elements of the traffic control system. This effort will provide a basis for detailed design of the system subelements and help in the identification of the constraints.

Constraint evaluation permits consideration of specific limiting conditions such as (a) funding, (b) time requirements, (c) legal, (d) political and others. The constraint evaluation process will screen the candidate systems, however, it should not be allowed to necessarily inhibit the conceptual design process. This process will result in a list of several (10 or less) candidate systems for possible implementation.

13.54 Analysis and Evaluation of Alternatives. Cost/benefit analysis and cost/utility analysis are the commonly used techniques for selection of the single best alternative. A cost/benefit analysis is very desirable providing that all the effects of the system can be quantified in monetary terms. This includes capital costs, operating costs, and maintenance costs through the life of the system as well as the benefits (both positive and negative) to society. Benefit quantification is difficult for such items as delay reduction, accident reduction, reduced system failures, improved driver information and similar items.

Cost/utility analysis is designed to measure the "utility" of a candidate system which is not directly convertible to dollar value, but can be directly compared to the "utility" of another candidate system. The "utility" is determined by assigning arbitrary weights to defined and measurable system features. Each system is rated in accordance with its ability to meet the system objectives and the utility rating calculated. If this technique is used objectively the resulting "utility rating" can be used to rank order candidate systems.

13.55 Plans and Specifications. In addition to the standard drawing and specifications, complex traffic control systems require some special specification items.

Deliverable Services. The deliverable services specification should include a detailed identification of the services to be provided by the contractor during installation, prior to acceptance by the operating agency and during the first several years of operation. The level of system documentation (operating manuals, parts lists, schematic diagrams, software documentation, etc.), any training to be required for operating personnel, the support staff to be provided during installation and testing of the system hardware, warranties or guarantees expected, maintenance especially on interface and trans-

mission equipment and the specific system acceptance tests that will be used should all be specified.

13.56 Routine Operations and Management Requirements. The successful implementation of a traffic control system does not end the problems for the traffic control engineer. The success of the system will depend on his ability to manage the system and keep it operating efficiently on a day-by-day basis. Three basic considerations are involved: a) operation of the system, b) maintenance of the system and c) evaluation of the system operation.

The system must operate in the full public view and, therefore, any system malfunctions (either technical or component) will be quickly identified. Also, there is a trend toward almost continuous computer operation of the system. Thus, the problem of staffing the control center for system monitoring, data collection and analysis, and system updates is a primary one. Coordination with the multiplicity of governmental agencies involved is also a critical management problem.

The maintenance of traffic control systems involves two basic types: a) scheduled and b) unscheduled. The scheduled maintenance program should be designed to keep the unscheduled maintenance activities to a minimum.

Traffic control systems are justified on the basis of projected improvements. Evaluations should be made to confirm or reject these projected benefits and to identify system modifications which will result in greater public utility. "Before" and "After" studies form the basis for a valid system evaluation procedure. Based on the system evaluation studies, the system can be updated as required to meet changing traffic demands.

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CHAPTER 14

TRANSPORTATION ALTERNATIVES AND THE STREET NETWORK

SESSION OBJECTIVES:

1. *To summarize the transportation alternatives available to reduce demand and increase the capacity of existing transportation facilities.*
2. *To summarize the interrelationships of various alternatives.*
3. *To discuss some of the considerations to be given to transportation improvements in the planning process - both long-range improvements and transportation system management improvements and in the development of a transportation improvement program.*

14.1 INTRODUCTION

In this course, we have attempted to present the principal alternatives available to the transportation manager for the improvement of urban transportation. We have concentrated on the short-range, quick pay-off alternatives in an effort to deal with the problems that are upon us now. This is not to say that long-range plans are not needed. They are, indeed, an important element in providing transportation for the future.

For a moment, consider two very general alternatives that are, in theory, available to us today: (1) improve our existing systems by making them operate more efficiently, or (2) expand the existing systems to accommodate the increases in demand at the same efficiency level of today. It is time to face the facts - our system is mature. We have not added a new transportation facility concept since the 1950's and there is not a major breakthrough on the horizon. Furthermore, the transport vehicle has not been advanced appreciably since the 1950's, but it is a more efficient vehicle today than it was in the 1950's. Can we say the same for the system? Is it handling more person trips than in the 1950's? Can the system handle more? Obviously, the answer is yes, if we are willing to concentrate our efforts on improving the system.

14.2 REVIEW OF ALTERNATIVES

14.21 Alternatives for Reducing Demand. As a quick review of the alternative improvements to urban transportation, there are alternatives that serve to reduce the demand for transportation. Such reductions in demand may be realized by reducing the number of person-trips, reducing the number of ve-

hicle trips by increasing the number of person-trips per vehicle, or by shifting person-trips out of the critical peak period demand. Alternatives that are available to the transportation manager for reducing demand include:

- Transportation Pricing. The process of imposing costs on those being transported, commensurate with cost to society for performing the transportation service. Some pricing alternatives have worked; others have failed, and for others, the true effectiveness is yet undetermined. However, there is one side benefit of rational transportation pricing; even if it fails to reduce demand, it places transportation costs on those who receive the benefits.
- Peak Hour Demand Management. The process of regulating work schedules to spread the peak hour demand is a very effective alternative, but does not fall within the total jurisdiction of the transportation manager. Providing the leadership in the implementation of variable work hours through business, industry and government will certainly test his managerial capabilities.
- Ride Sharing Programs. Increasing the occupancy of vehicles using transportation facilities through ride sharing programs will certainly increase the efficiency of the system. In one major city, it is estimated that 500,000 daily work trips are made in vehicles with single occupants. If 20 percent shared rides, this would be a reduction of 100,000 trips daily. Ride sharing requires incentive, opportunity and marketing. Opportunity is provided through carpools, vanpools, subscription bus service, etc.; incentive is provided through pricing, convenience, and reduced hassle; and marketing is provided through good management.
- Improving Public Transportation. Improving or instituting public transportation systems in congested metropolitan areas can be significantly beneficial. Implementation efforts must be three-fold: technology, management, and marketing. For example, technology has provided bus rapid transit, but it can be effective only if it is managed to meet the needs of the ridership and sold to the clientele through specific marketing programs.
- Bicycling. The popularity of the bicycle has increased tremendously in recent years, and it serves certain needs very effectively. At this point in time, the bicycle has minor

potential in reducing the transportation demand on existing systems. However, the transportation manager should consider the safety and service aspects of the increasing number of bicycle riders in the urban area.

14.22 Alternatives for Increasing Capacity. The transportation manager can compound the improvements to the transportation system if he is able to increase the number of person-trips per vehicle, and then, by the implementation of other alternatives, increase the vehicular capacity of the transportation facility. We have discussed a number of alternatives that relate directly to increasing the capacity of transportation facilities.

- Improving Urban Goods Movement. One of the major restrictions to capacity of the street system (and sidewalks) in the CBD is the movement and curbside parking of trucks involved in the pick up and delivery of goods. Provision of off-street loading facilities is a long-range solution, but significant short-range benefits may be realized by regulation of curbside activities.

- Improving Pedestrian Facilities. Every trip begins and ends with pedestrian movement, and in many instances it is the only realistic mode of travel. Through the proper planning, design, and operation of pedestrian facilities, pedestrian travel may be enhanced, and urban transportation improved greatly. Improved sidewalks, traffic controls, grade separations, malls, and other pedestrian systems increase the safety and operational efficiency of transportation.

- Improving Traffic Operations. How we utilize or operate available transportation facilities determines to a great degree the efficiency of these facilities. Making improvements to traffic flow patterns, minor design features and regulatory measures can be quick pay-off alternatives for improving urban transportation. Such alternatives include intersection improvements, access regulation, one-way street systems, unbalanced flow, and others.

- Freeway Operations Management. We have found that freeways are efficient, capacity-wise, if reasonable operating conditions can be maintained. Congestion, whether induced by excessive demand or a specific incident, results in reduced operational efficiency. Therefore, a major improvement to urban transportation may be achieved by managing the urban freeway system to achieve peak efficiency.

14.3 IMPLEMENTATION OF IMPROVEMENT ALTERNATIVES

Due to the complexity of urban transportation and the various local factors influencing transportation needs and resources,

no single, clear-cut alternative is sufficient. In fact, the transportation manager will be involved in the selection and implementation of several alternatives simultaneously in an effort to provide a workable system. Thus, it is essential that we give some consideration to the process of analyzing and selecting alternative solutions to transportation problems.

- Establishing Community Goals and Objectives in Transportation. This is a very important element because the transportation manager cannot implement alternative solutions that are in conflict with community goals. The transportation manager can and should have considerable influence in setting these goals and objectives, because he best understands the limitations in technology and resources that will affect the establishment of realistic goals and objectives.

- Identification of Transportation Problems. Superficially, transportation problems are identified by the occurrence of severe congestion on transportation facilities and its effect on the environment and society in general. However, the cause of the problem is more elusive and leads to the next step.

- Analyzing the Problem and Identifying Alternative Solutions. It is necessary that transportation problems be traced back to their true cause in order to identify workable solutions. The problems must be analyzed in terms of their relationship to the total transportation system rather than a subsystem component. For example, seeking a solution to a capacity problem on the freeway system is not sufficient until the total corridor travel demand and the capabilities of other corridor transportation facilities have been analyzed.

- Selection of Alternative Solutions. In selecting alternative solutions, it is necessary that the interactions of combinations of alternatives be considered in order that the solutions may be complementary rather than contradictory. For example, the implementation of carpooling programs may be contradictory to existing or proposed implementation of express bus service. Most experience to date indicates that parallel programs are not contradictory, but the fact is we have insufficient experience with parallel programs at this time. Because there is a lack of experience in these matters, urban transportation management should take action to keep abreast of activities in other urban areas.

14.4 COORDINATION OF PLANNING, DESIGN, AND OPERATION

Even though we have been stressing the implementation of short-range improvements to the existing urban transportation system, we must not lose sight of the value of an orderly process of planning, design, and

operation of transportation facilities. Even though our current system is maturing, we will not cease to expand, re-build and replace parts of the system to satisfy future needs. For this reason, we should review some of the aspects of good coordination.

14.41 Planning. Planning is the key to providing a transportation system which will meet the needs of the future. In the development of a transportation plan, inputs from many sources must be obtained. These inputs need to include those which will help develop a system that will satisfy the social, economic, and environmental goals of the urban area. From a technical point of view, the design and operational aspects of the system must be considered to assure that the various elements of the system are in "harmonic balance" or compatible within the system. These elements refer to both intermodal and intramodal.

For example, intermodal balance would provide for the various travel needs that exist in a corridor - autos cannot satisfy all trip makers needs, nor can rapid rail or bus, each by themselves. But a combination can provide a mode to match a particular need. Further, this modal balance must relate to land users, and make provisions to control land uses and access so that all modes will function as planned. Intermodal balance also refers to the transfer and combination of modes to satisfy the trips. This transfer needs to be assumed and protected.

Intramodal balance refers to those elements of a particular modal subsystem. For the highway system these would be: sufficient number of the various functional classes of streets, proper location, and sufficient right-of-way.

14.42 Design. Design of the transportation system should be based on the transportation objectives which would cover the life of the facilities comprising the system. This is rather difficult considering that the various facilities have varying degrees of permanency. Rail facilities may last 70 to 100 years, and highways may last only 20 to 40 years. Therefore, the design standards that are developed must consider technological changes that may occur resulting in basic changes of geometric and support equipment design.

Flexibility is the key to good design. Our inability to accurately predict transportation needs in the future makes flexibility in design a very important factor. Changing the "face" of the facility is far more practical than changing the complete structure of the facility.

The design must satisfy the operational objectives of the facility. Thus, it is necessary that the design process include strategic operational reviews.

14.43 Operations. Traffic operations is the day-to-day regulation of the use of a traffic facility to produce the desired end result, a service to the public. As indicated previously, the success of the operations element is greatly dependent upon how well the planning and design processes were carried out. On the other hand, operations is more complex than the mere mechanical processes of implementation and maintenance. To achieve maximum efficiency from a system, the operations engineer must assume a role of management. He must manage the process of moving people and goods which includes, but is not limited, to regulation. The operations manager must be concerned with the distribution of travel with time, specifically within peak periods; he must be concerned with operational characteristics which increase the capability of the system to accommodate people; and, he must be concerned with providing an acceptable interface with the various transportation modes.

Traffic operations has the advantage of requiring low-capital or non-capital expenditures and, therefore, requires a shorter implementation time than the planning/design elements of the total transportation process. For this reason, operations can assume a shorter range of sufficiency, and stage development may be used to increase the effectiveness of available resources. However, traffic operations should not be relegated to the position of a reactionary process.

14.5 THE STREET AS A TRANSPORTATION CORRIDOR

Transportation corridors can consist of many modes of transportation - including but not limited to highways utilizing auto, bus, and truck modes; rail modes; and even pipelines. The whole urban area's development is affected by the capacity and operation of these corridors. All modes are important and must be considered in the development of a particular corridor. However, every city throughout history and probably in the foreseeable future has had or will have one transportation element which is a principal influence on the urban character - the street and highway system. This basic character will be influenced and varied by other transportation modes provided.

Since the streets and highways constitute the primary transportation element in a community at the present time and will for the foreseeable future, it is important to discuss the functions of this element.

14.51 Review of Street Functions. The current functions of street systems are defined as the movement of people and goods in vehicles (all compatible types), and access to the land. Additionally, the street may serve pedestrian movements, utilities, vehicle parking, storage, and various and

sundry functions related in some way to land use. Thus, the street is a corridor that serves a general need.

If we compare this current function to some period in the past, say 100 years, we find that the functions have not changed. Even then they served as corridors for movement and access. The changes have been made in the vehicles that use the street and in the accommodations for those vehicles.

If we should look to 100 years in the future, we can in no way predict the manner in which the street may be used, i.e., the form of vehicle, but we can be confident that the functions will be the same so long as society's needs are manifested in mobility and land access.

14.52 Development of A Street Network.

14.52.1 Major Street Plan. A major street plan is essential for the orderly growth and development of an urban area. As an integral part of the overall transportation plan for an urban area, the major street plan constitutes the skeletal framework for all transportation modes accommodated within the street right-of-way. A major street plan is generally related to the development of new areas of the city, designed to provide guidance in developing a functional arterial system in the new areas. It is equally important to the existing system. The major street plan provides a basis for transportation management to set priorities for upgrading existing facilities, improving control systems, and for improving transit services.

Traditionally, the major street plan has been a product of the planning segment of the transportation profession, because it first serves the function of promoting orderly development of land use. However, the major street plan serves the designer in identifying the general requirements of the system that must be provided for in design, and finally, serves the operations segment in identifying the general requirements for managing the operations of the street network. Thus, the major street plan is one of the elements that ties the planning/design/operations elements together.

14.52.2 The Need for Functional Classification. The functional classification of streets is a prerequisite to the development of a major street plan. Classifying streets according to their function, whether movement, access or a combination of both, permits the coordination of planning, design, and operation to satisfy land use according to public need.

The guidelines for functional classification of streets are provided in an FHWA document, "Highway Functional Classification - Concepts, Criteria and Procedures," Transmittal 155, Volume 20, Appendix 12, July 1974.

This document identifies four classes of Urban Streets:

- Principal Arterial. This system of streets and highways serves the major centers of activity of a metropolitan area, the highest traffic volume corridors, and the longest trip desires; and carries a high proportion of the total urban area travel on a minimum of mileage. The system should be integrated, both internally and between major rural connections. The principal arterial system is stratified as follows: (1) Interstate, (2) other freeways and expressways, and (3) other principal arterials (with no control of access).

- Minor Arterial. The minor arterial street system should interconnect with and augment the urban principal arterial system and provide service to trips of moderate length at a somewhat lower level of travel mobility than major arterials. This system also distributes travel to geographic areas smaller than those identified with the higher system. The minor arterial street system includes all arterials not classified as principal and contains facilities that place more emphasis on land access than the higher system, and offer a lower level of traffic mobility.

- Collector Street. The collector street system provides both land access service and traffic circulation. It differs from the arterial system in that facilities on the collector system may penetrate residential neighborhoods, distributing trips from the arterials through the area to the ultimate destination. Conversely, the collector street also collects traffic from local streets in residential neighborhoods and channels it into the arterial system. In the central business district, and in other areas of like development and traffic density, the collector system may include the street grid which forms a logical entity for traffic circulation.

- Local Street. The local street system comprises all facilities not on one of the higher systems. It serves primarily to provide direct access to abutting land and access to the higher order systems. It offers the lowest level of mobility and usually contains no bus routes. Service to through traffic movement usually is deliberately discouraged.

14.52.3 Street Network Layout. To maintain the integrity and operational efficiency of urban streets, the functional layout of the street network is as critical as the design of the individual streets. There are certain basic rules or guidelines that are essential for good system operation. Generally, a system of spacing, intersection/connection, access, and land use separation exists and should be developed and adopted by an urban area.

14.53 Design Standards for City Streets. Every incorporated city should have published design standards for city streets. These standards should be presented in a concise document that is understandable by planners, developers, and various city officials. It is not sufficient to simply adopt a manual such as "A Policy on Design of Urban Highways and Arterial Streets," by AASHTO. This is an excellent reference for the designer's reference shelf and should be used as a guide to develop local design standards. To be effective, design standards must be established through the coordinated efforts of city departments, and accepted by the various agencies that must follow the standards.

Design standards assure geometric and operational consistency. In the whole scheme of transportation, the major street plan establishes the skeletal framework of the street system. The functional classification system identifies the function of each of the elements of the system, and then the design standards outline the physical requirements of each of the various street classifications necessary to assure satisfactory traffic operations. Therefore, it is essential that the traffic operations and geometric design groups of the city government have a major role in the development of design standards.

14.6 COORDINATION OF LONG-RANGE IMPROVEMENTS WITH IMPROVEMENTS TO THE EXISTING SYSTEM

There is no question that the greatest efficiency in urban transportation will be realized through the coordination of current transportation improvement activities with the long-range planning process to meet future transportation needs. The greater opportunity for coordination is made possible and, in fact, required through the provision that the urban transportation planning process result in a two-element plan consisting of a long-range element and a Transportation System Management element. Thus, both elements are the responsibility of the local agencies to be carried out through the Metropolitan Planning Organization.

Combining the two elements under "one roof" will lessen the tendency to isolate the planning and implementation relative to the various modes. For example, provision for public transit systems and major highway improvements may be planned to be comple-

mentary rather than contradictory or subservient. This is exemplified by the latest freeway plans such as the expansion of the Gulf Freeway in Houston which provides a central right-of-way allowance for mass transit operations. Others are incorporating the immediate provision of exclusive bus lanes. Such planning should be extended to providing right-of-way for future fringe area terminals abutting the freeway, and the construction of feeder routes to these and other mass transit terminals. Taking the balanced multi-modal approach to planning and implementation activities may result in fewer freeway lane - miles or RRT track miles constructed; but with judicious application it should result in a more efficient urban transportation system.

14.7 DEVELOPMENT OF A TRANSPORTATION IMPROVEMENT PROGRAM

The basic purpose of the T.I.P. is to facilitate the implementation of projects that are required to provide the planned transportation system. There are several considerations which must be given to this program development.

One consideration includes the selection of projects that will result in an orderly improvement sequence. Generally, the projects implemented must be usable as soon as possible to assure the maximum benefit for the investment. However, this must be tempered with the community's development needs so that the desired land use and access are assured.

Another consideration is the cost of the projects and available resources. The program must be realistic to assure orderly implementation and avoid broken promises to the general public.

Also, consideration should be given to which projects should be implemented to achieve the other goals of the community such as energy conservation, air pollution reduction, revitalizing a particular area, etc.

The development of the T.I.P. will require a combining of long-range and transportation system management projects to assure that both existing and future problems are adequately addressed. Each individual area will have to develop criteria for the combining of these two types of projects so that their own particular needs can be addressed.

