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MPARISON OF COSTS AND BENEFITS OF ITIES FOR PEDESTRIANS

W. G. Scott and L. S. Kagan

December 1973
Final Report

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16. Abstract

This report discusses the costs and benefits of facilities for improving pedestrian circulation, safety, and environment. The report categorizes the various types of facilities and improvements for pedestrians in downtown areas and at grade separation projects. A general framework for estimating total facility cost over time is developed and examples of costs are provided. The nature of pedestrian travel is examined as an aid to determining the requirements for and impacts of pedestrian facilities. The cost and benefit impacts of facilities upon pedestrians, vehicles, and abutting properties are each examined. Finally, examples of cost and benefit analysis of highway crossings are provided along with case studies of grade separated facilities in central business districts.

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UNITED STATES GOVERNMENT
Memorandum

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

TO : Regional Federal Highway Administrators
Regions 1, 3-10

DATE: January 7, 1975

In reply refer to: HRS-40

FROM : Director, Office of Research

SUBJECT: Transmittal of Research Report No. FHWA-RD-75-7, "A Comparison of Costs and Benefits of Facilities for Pedestrians."

Distributed with this memorandum is the subject report with immediately implementable results. The report will be of interest to highway traffic engineers, and urban planners. The report is intended to consolidate available data and research into a form suitable to serve as a guide to individuals concerned with the separation of pedestrian and vehicular movement, and specifically addresses the costs and impacts of pedestrian facilities that incorporate elements of vertical separation. Elements of horizontal separation such as malls are treated in a limited way for completeness, but are not given extended consideration since a proliferation of available data exists.

In this report, an attempt has been made to go beyond the more basic elements of movement to identify, quantity and provide insight into the factors that influence pedestrian movement, pathway choice and facility utilization. For facility costs, specific cost contributing factors are identified, and in most cases, quantitative estimates given. Particularly signigicant is the structured breakout of those costs which are facility-related; that is independent of site location, and those that are specifically site-related; in this way many of the hidden costs of facility construction, operation and maintenance are given visibility. General sections on cost and impact are supported by specific sections dealing with highway crossing facilities and grade separated facilities in central business districts.

In terms of scope, this report does not provide facility design specifications; it addresses the planning and functional concepts, rather than the construction specification and engineering aspects of facility design. Nor does it specifically address system warrants, although it can provide valuable input into that decision process.

Distributed with this memorandum are sufficient copies of the report to provide a minimum of four copies to each regional office, two copies to each division office, and four copies to each state highway agency. Direct distribution is being made to the division offices. Additional copies for official use may be requested from Mr. David Solomon, Chief, Environmental Design and Control Division, FHWA, HRS-40, Washington, D. C. 20590. Additional copies for the public are available from the National Technical Information Service, Department of Commerce 5285 Port Royal Road, Springfield, Virginia 22151. A small charge will be imposed for each copy ordered from NTIS.

D. Solomon
for Charles F. Scheffey

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CHAPTER 1. SCOPE OF THE REPORT

1.1 INTRODUCTION

Anyone who has ever attempted to venture across a street or highway on foot is familiar with the conflict that exists between motor vehicles and pedestrians. From the earliest recorded history when the use of paths by people on foot was first challenged by people on horses, to the present when walking is often at the mercy of the automobile, the rights of pedestrians have declined. In many environments, coexistence to the pedestrians means the risk of personal injury, the inconvenience of delays created by barriers of vehicles, and the discomfort of automotive noise and fumes.

One response to the problem of pedestrian-vehicular conflict is to provide separate pathways, and at times, entire separate environments, for exclusive pedestrian use free from vehicle intrusion. At present, pedestrians and vehicles share what is essentially the same space. At signalized urban intersections, they are separated only by time, and even here the separation often is not complete due to the interference between crossing pedestrians and turning vehicles. However, various means exist to effect more defined systems of separation. The two basic system elements which can be used either singly or in combination are categorized as horizontal and vertical separation. Horizontal separations (excluding sidewalks) are those for which the movements of pedestrians and vehicles are displaced horizontally and separated by some substantial physical or spatial barrier. Vertical separations are those for which the two movements are vertically displaced with the pedestrian circulation occurring either over or under that of the vehicles. Horizontal separation has reached its highest form to date in the pedestrian mall typified in many suburban shopping malls, but more interestingly found in the closing and conversion of vehicular street to form exclusive pedestrian precincts. Vertical separation, used for many years by highway engineers in the form of pedestrian bridges and tunnels across busy streets and highways, has more recently been applied by urban planners and developers in the expanded form of walkway systems.

The primary thrust differs, however, between the application of vertical separation by the highway traffic engineer and that by the urban planner. The highway engineer's primary concern with separation is as a tool with which he can improve safety and capacity of roadways. The urban planner, on the other hand, is primarily concerned with the efficient linkage of urban land uses via the dominant means of movement in these areas -- walking. Studies of vehicle delays at urban intersections by traffic engineers almost universally ignore pedestrian movement which often has a substantial effect, especially on turning vehicles. Urban planners, on the other hand, who often mention the relief of vehicular congestion as a benefit of separation, prefer to emphasize descriptions of the freedom and pleasant surroundings in store for pedestrians. However, the highway planner introducing a pedestrian bridge over a heavily travelled highway is not only eliminating a potential source of vehicle delay, but also is providing a safe, and at times, efficient linking of land uses. Conversely, when the urban planner provides an elevated walkway system to reduce the barrier effect of vehicles on pedestrian circulation, he is also creating the potential for fewer conflicts and relief of vehicular congestion.

This report is intended primarily for this combined group of highway traffic engineers and urban planners. Its purpose is to consolidate available data and research into a form suitable to serve as a guide to individuals concerned with the separation of pedestrian and vehicular movement, and specifically addresses the costs and impacts of pedestrian facilities that incorporate elements of vertical separation. Elements of horizontal separation such as malls are treated in a limited way for completeness, but are not given extended consideration since a proliferation of available data exists.

Nothing comparable to the extensive data on malls exists for grade-separated facilities. Most of what is available is scattered, unorganized and of little use to planners because of its general nature. There is a great amount of research that deals with the characteristics of basic pedestrian movement such as walking speeds, distances and times and the capacities of walkways. While this information is extremely useful to planners, its applicability is limited.

In this report, an attempt has been made to go beyond the more basic elements of movement to identify, quantify and provide insight into the factors that influence pedestrian movement, pathway choice and facility utilization. For facility costs, specific cost contributing factors are identified, and in most cases, quantitative estimates given. Particularly significant is the structured breakout of those costs which are facility-related, that is, independent of site location, and those that are specifically site-related; in this way many of the hidden costs of facility construction, operation and maintenance are given visibility. General sections on cost and impact are supported by specific sections dealing with highway crossing facilities and grade separated facilities in central business districts.

In terms of scope, this report does not provide facility design specifications; it addresses the planning and functional concepts, rather than the contruction specification and engineering aspects of facility design. Nor does it specifically address system warrants, although it can provide valuable input into that decision process.

1.2 ORGANIZATION OF THE MANUAL

Chapters 2 through 8 are divided into four distinct groups. Chapter 2 defines pedestrian facilities and includes a detailed typology. Chapter 3 is concerned wholly with facility costs, cost adjustment and cost synthesis for decision-making purposes. Chapters 4, 5, and 6 deal with the relationships between pedestrian movement and facility impacts. Chapters 7 and 8 are devoted to specific facility types, namely highway crossings and central business district systems, respectively. Brief chapter summaries are presented below.

Chapter 1 - This chapter contains an introduction, an overview of the manual contents, and some suggestions for its use.

Chapter 2 - Chapter 2 provides an introduction to pedestrian circulation systems with definitions and examples of system elements. Detailed descriptions of various types of horizontal and vertical elements of pedestrian separation facilities are given. An overview of the interrelation between facility characteristics and facility impacts is provided to serve as an introduction to Chapters 4 through 6.

Chapter 3 - A detailed examination of facility costs and cost influencing factors is contained in Chapter 3. Facility-related factors which are independent of site or location are described and a method for synthesizing them into a base facility construction cost is provided. Cost elements that are site-related are introduced, leading to determination of an unadjusted facility construction cost, followed by a brief comparative cost analysis for specific elements. Methods for making geographic and temporal adjustments, and operating and maintenance costs are discussed. Finally, the present value and equivalent uniform annual cost methods of economic analysis are presented.

Chapter 4 - The basic concepts of pedestrian trip attraction and generation necessary for facility utilization and success are presented in this chapter. Trip purpose, as a basic trip variable, is introduced, and pedestrian trip characteristics by trip purpose are discussed in detail.

Chapter 5 - This entire chapter deals with facility impacts on pedestrians, and addresses the relationship between pedestrian benefits, perception of benefit and facility utilization. In particular, pedestrian safety is discussed in detail, convenience is described as it relates to important facility pathway attributes, and comfort and other impacts are given attention. Gross estimates of the costs of pedestrian accidents and the costs of pedestrian delay are derived for comparison on the basis of relative magnitude.

Chapter 6 - Impacts on motorists, abutting property owners, and others are described. An estimate of the cost of vehicular delay is obtained to allow comparison with similar pedestrian-related measures developed in Chapter 5.

Chapter 7 - Chapter 7 deals specifically with highway overpasses and underpasses. Benefits peculiar to highway crossings are described, and a series of representative case studies, for both proposed and actual facilities, are presented to show different methods of approaching the cost and benefit analysis of these facilities. A brief section discussing the comparative choice of alternatives is included.

Chapter 8 - This final chapter is devoted to grade separations in central business districts. The approach utilizes a series of extensive case studies to illustrate the complex system of events and circumstances that influences the development of these systems. Costs are provided where available, and the relative success of the systems and system elements is discussed where appropriate.

1.3 USE OF THE MANUAL

This manual should be used within the context of a comprehensive planning process. The development of a successful pedestrian system will often go far beyond the elements discussed here, especially for large-scale, complex systems where experience, as noted in the case studies contained in Chapter 7, indicates that the conception, implementation and operational phases of these systems is generally an evolutionary process covering many years. In addition to consideration of immediate costs and pedestrian impacts, factors such as the dynamics of the market, private and public leadership, political climate, availability of resources, and the location and timing of urban renewal and/or private development are inherent in the process. Many systems are conceived only because the opportunity exists in connection with new urban development. For more elementary systems such as a highway overpass, or single downtown pedestrian bridge, the planning process is usually much simpler and contracted in time, but even here the consideration of facility costs and impacts will often be only one ingredient in the mixture of influencing factors.

Given that other factors are being given attention, this report can provide a tool for increasing the awareness of specific considerations that should be included in the process for planning and implementing pedestrian facilities. Chapter 5 is particularly important in this regard. In many cases, expensive pedestrian facilities remain unused because pathway elements such as directness or continuity have either been ignored, misunderstood or compromised in favor of design aesthetics or similar criteria. In one example a costly pedestrian bridge across a multilane highway goes virtually unused because it connects activity centers with only minimal trip exchange potential and which are so far apart that only a small propensity to walk exists; this illustrates the lack of understanding of the basic concepts noted in Chapters 4 and 5. A multimillion dollar pedestrian walkway system in an urban center stands like a strange monument totally unused because the phasing of construction, and other basic concepts discussed in the case studies in Chapter 8 were ignored. This report should serve as a guide to the factors that influence facility utilization and result in facility success.

A second basic use is as a cost planning and estimating guide specifically tailored to elements of pedestrian facilities. Chapter 3 serves to identify and isolate cost elements, including many hidden costs that are often overlooked. In many cases where two competing alternatives are being considered, cost alone can be a deciding factor since benefits accruing to either element may be equal (or nearly so); this is often the situation in the choice between a highway underpass and an overpass. In more complex systems, an economic analysis based on the cost elements denoted in Chapter 3 can help to narrow down the multitude of possible alternatives so that attention can be focused on the impact of the remaining options.

CHAPTER 2. PEDESTRIAN CIRCULATION SYSTEMS AND FACILITIES

This chapter is devoted to the subject of pedestrian movement and facilities in general and serves to introduce the topics that are examined in more detail in later chapters. Pedestrian circulation systems are discussed in the first section within the context of a network of nodes that generate and attract pedestrian trips connected by pathways along which these trips are made. The next section covers pedestrian facilities as specific network elements which are designed primarily for the use of people on foot; an inventory of facilities with descriptions is given. In the third section, the impacts of these facilities on pedestrians, motorists and others is described, and the relationship between facility design, utilization and impact, examined. Finally, the important subject of pathway choice as it relates to facility utilization is covered.

2.1 THE PEDESTRIAN SYSTEM

The primary component of the pedestrian system is, of course, the person doing the walking. Numerous studies have addressed the nature of the pedestrian -- how fast and how far he walks, where and why he walks, and so on. As applicable, this material is utilized in the later chapters; however, for the purpose of this chapter, the meaning of a pedestrian system will be restricted to the physical environment in which walking takes place.

Pedestrian activity occurs within an often complex and sometimes ill-defined system composed of diverse walking paths linking centers that attract and generate trips. While one usually thinks of the central urban core of cities in this context because of their concentration of activity, the concept of a pedestrian circulation system is just as applicable to suburban pedestrian movement as it is to the downtown itself. This system can be viewed as a network in much the same way as vehicular circulation systems. As shown in Table 1, one of the two primary elements in the pedestrian network is the node, or centroid, which acts as the origin and destination of the walking trip. Nodes are centers of pedestrian activity, points of pedestrian concentration and the attractors and generators of pedestrian trips. These centroids are classified as two basic types:

I. NODES (OR CENTROIDS)

  A. PRIMARY (or terminal)

    1. Transit stops - bus, train, subway, etc.

    2. Parking areas

    3. Residential concentrations

  B. SECONDARY (or activity)

    1. Offices

    2. Retail stores

    3. Restaurants, theatres, etc.

    4. Vertical access points - stairs, ramps, escalators and elevators

    5. Pathway intersections

II. LINKS, (PATHWAYS OR WALKWAYS)

  A. VEHICLE-DOMINANT

    1. Sidewalks

    2. Crosswalks

  B. PEDESTRIAN-DOMINANT

    1. Horizontal separations

    2. Vertical separations

    3. Time separations (Street Malls)

TABLE 1

PEDESTRIAN SYSTEM TERMINOLOGY AND EXAMPLES

- Primary (or terminal) nodes - Those associated with mode-exchange where the basic walking trip begins and ends; examples include parking areas, transit stops and residences; and

- Secondary (or activity) nodes - Those centroids, other than primary, that attract trips from the primary nodes as well as from other secondary nodes; examples include offices, stores and restaurants.

Pedestrian movement between nodes is made via a series of linking pathways (also referred to as pedways and walkways) which are the second primary element in the network. For this discussion, the pathways will be considered in two categories:

- Vehicle-Dominant - Pathways that exist in, or share space dominated by vehicular movement; and

- Pedestrian-Dominant - Pathways that are reserved exclusively for pedestrian movement with no vehicular intrusion allowed except possibly 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 his walking trip may also reinforce this directness. However, the 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. In the next section, an inventory of various facilities designed specifically for pedestrian movement is provided and discussed.

2.2 PEDESTRIAN FACILITIES

Pedestrian systems, depending on the extent or complexity of the network, are composed of an aggregation of three basic types of elements defined by the way in which pedestrians and vehicles are separated:

- horizontal separation,
- vertical separation, and
- time separation.

The first two elements are usually incorporated into structures known as pedestrian facilities. The third element, time separation, is usually implemented within the context of existing vehicle-dominant pathways; primary examples are the alternating use of signalized street intersections by pedestrians during "all walk" phases or the temporary closing of streets for exclusive pedestrian use as malls.

Horizontally or vertically separated elements may be used as single elemental facilities such as a pedestrian bridge over a limited access highway; or in combination, to form a facility that comprises an entire network of pathways. These composite facilities may include horizontal or vertical elements only, or both in various combinations. Most systems implemented in large urban centers contain both types of elements.

In the following sections, representative types of separation are discussed. This discussion centers around the list shown in

Table 2, and is intended to be an overview of the numerous ways in which pedestrian and vehicular movement can be separated. Of course, variations on these basic themes are possible. Emphasis in the following discussion is on static facilities, and while analogous mechanical systems exist for many of these elements, they are not covered here.

2.2.1 Horizontal Separation

The primary elements of horizontal separation are categorized in two ways:

- Parallel - Systems that accommodate pedestrian movement at grade parallel and immediately adjacent to vehicular movement; and
- Displaced - Systems which, as a function of their location, are characterized by physical displacement from the vehicle network.

Parallel elements obviously begin with the ordinary sidewalk which was discussed earlier in this chapter. Basic improvements to more adequately accommodate pedestrians are widened sidewalks and arcade setbacks. A partial mall in which most but not all vehicular traffic is excluded is also a parallel horizontally-separated pedestrain system. Displaced elements are represented by full malls where all vehicular traffic is excluded, or by offsetting the parallel grid of sidewalks so that it occurs within the block structure instead of on its perimeter. Additional discussion and examples are given below.

Sidewalks

Sidewalks may be widened, as shown in Figure 1, by transforming existing parking lanes into added sidewalk space. The added space can then be used to partially buffer pedestrian movement from vehicular movement by the use of plantings, benches and similar barriers.

Partial Malls

The partial mall is simply a more complete treatment of the widened sidewalk. A stellar example is the Nicollet Mall in downtown Minneapolis (See full discussion in Section 8.4.3.). Nicollet Mall

HORIZONTAL SEPARATION

PARALLEL ELEMENTS

- Sidewalks
- Partial Malls (widened sidewalks)
- Sidewalk Setbacks (arcades)

DISPLACED ELEMENTS

- Displaced Sidewalk Grids
- Full Malls
- Street Closings (incl. temporary)

VERTICAL SEPARATION

BELOW-GRADE ELEMENTS

- Tunnels (highway)
- Tunnels, Subwalks, Subways (CBD)

ABOVE-GRADE ELEMENTS

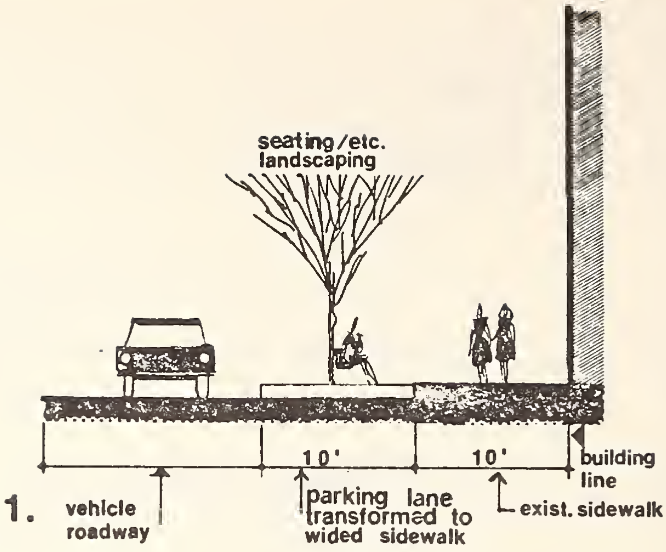
- Bridges (highway)
- Skywalks, Skyways, Elevated and Second-Level Systems (CBD)
  - independent
  - flanking (independent/integral)
  - integral
  - interior

CONNECTORS

(Stairs, Ramps, Escalators, Elevators)

TABLE 2

ELEMENTS OF SEPARATED PEDESTRIAN SYSTEM AND FACILITIES



SECTION

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 1

SIDEWALK WIDENINGS

limits vehicular intrusion to buses and taxicabs only, although through traffic is allowed on all cross streets perpendicular to the mall. The transitway is serpentine which breaks up the undesirable linearity of the street and allows a more interesting treatment of the resulting pedestrian spaces. Partial malls have most of the advantages and disadvantages of sidewalk widenings, except as in the case of Nicollet, where transit service to shoppers and workers in the area is improved by excluding other vehicles, and using part of added pedestrian space for bus shelters.

Arcade Setbacks

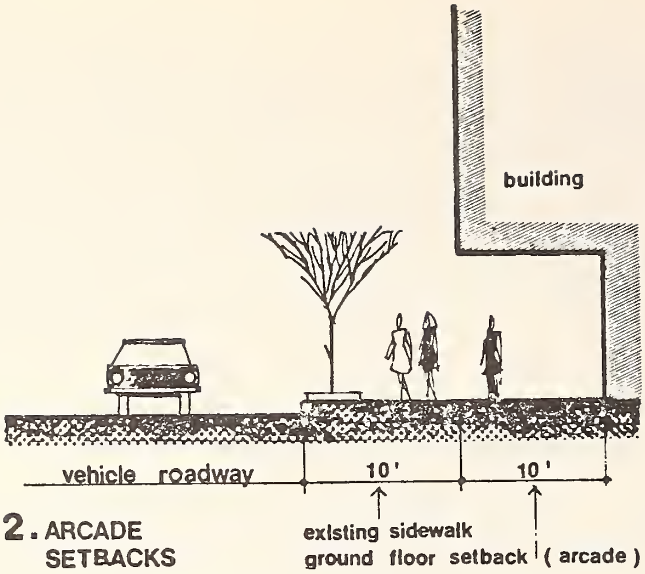
In new construction, or where old construction is being remodeled or rebuilt, the building abutting the sidewalk can be recessed to create additional pedestrian space as shown in Figure 2. This provides the advantages of sidewalk widening while maintaining the original roadway width. It also provides partial cover from the elements.

Full Malls

Full malls, shown in Figure 3, are probably the best-known examples of horizontal, pedestrian-vehicular separation. They usually occur when a main shopping street is closed to all but emergency traffic; traffic may be maintained on all, some or none of the cross streets within the mall area. Temporary street closings (separation by time) is a special case of this treatment. Malls can be covered or enclosed to provide benefits to pedestrians beyond those provided by separation.

Displaced Grids

A displaced grid of horizontally separated pedestrian walkways is often configured as shown in Figure 4. In some cases, this treatment can be created by converting alleys into pedestrian space, and opening the backs of retail shops abutting the alleys; the store backs then become the store fronts. In other cases, the displaced grid may be formed by shopping arcades or lobbies within the interior of office buildings or hotels.



SECTION

ADVANTAGES

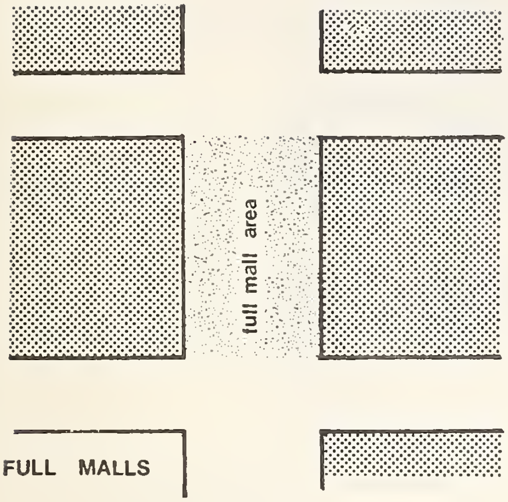
- Relief of pedestrian congestion
- Buffer zone reduces potential for conflict and accident
- Reduced annoyance from fumes and noise
- Increased space for pedestrian amenities
- Some shelter from sun and inclement weather
- Does not reduce vehicle space

DISADVANTAGES

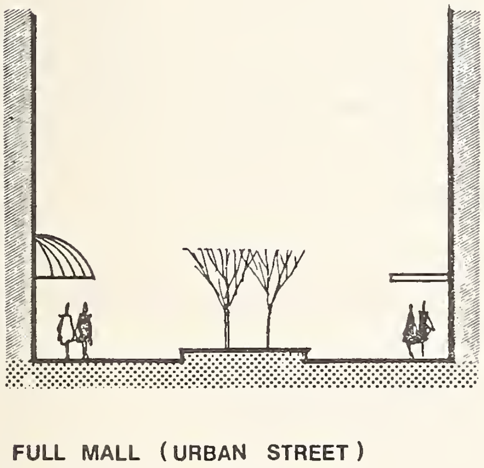
- Does not solve the problem of conflict at intersections
- Depends on cooperation of builders, developers and other private interests
- Reduces store frontage and retail sales space

FIGURE 2

ARCADE SETBACKS



PLAN



SECTION

ADVANTAGES

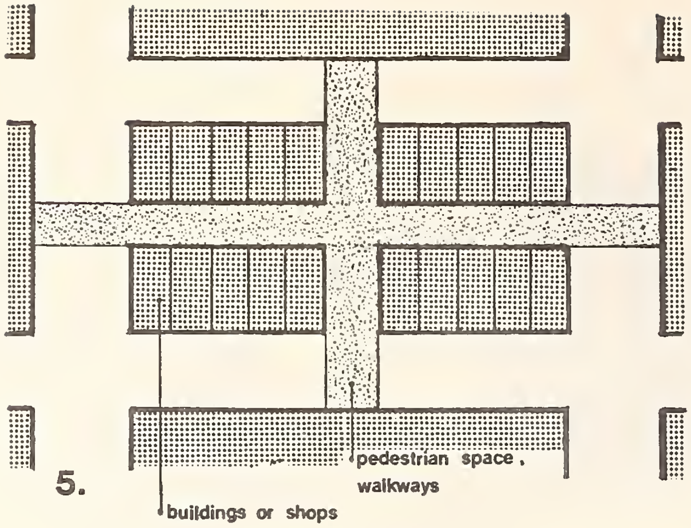
- Eliminates conflict within mall area
- May be integrated with public transit
- Allows use of people-movers, jitneys, etc.
- Can be developed in stages
- Allows a wide range of communal activities (art fairs, craft shows, entertainment, etc.)
- Can integrate with existing parks, plazas, etc. to create "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 3

FULL MALLS (URBAN STREETS)



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 eliminates conflicts with turning vehicles and simplifies 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 signalized.
- Requires extensive remodeling when incorporated into existing buildings.

FIGURE 4

HORIZONTALLY DISPLACED GRIDS

2.2.2 Vertical Separation

Like horizontal separation, elements of vertical separation are broadly categorized in two ways:

- Below-grade systems such as underground concourses or tunnels where vehicular movement is above and pedestrian movements is below, the terms subwalk, pedestrian subways and pedestrian tunnels are used interchangeably.

- Above-grade systems on which pedestrian movement occurs above vehicular movement; the terms skywalks, skyways, elevated or second-level walkways and pedestrian bridges are used interchangeably to describe systems and elements.

Underground systems have been utilized in several Canadian cities as well as many in Europe. Portions of both the Montreal and Toronto systems (see Sections 8.4.1 and 8.4.2) are underground. This solution is often implemented when the opportunity exists to utilize an already existing subterranean system such as subway stations and similar underground transit terminals. Above-grade systems include a wide variety of elevated skyways. The skyway solution is often implemented when conditions warrant separation but the expense of depressing walkways or elevating the streets is prohibitive. One of the best known elevated systems is the skyway system of midblock connections in Minneapolis (See Section 8.4.3).

Below Grade Elements

Pedestrian subways can be classified on the basis of their principal method of construction as follows:

(1) Cut and Cover - a system which is constructed by partially removing (cut) the roadway surface to allow the construction of the underpass and subsequently replacing (cover) the roadway surface and returning the highway to normal operation.

(2) Tunnelling - a system which is totally constructed beneath a highway right-of-way with no alteration to the roadway surface during the course of construction.

The cut and cover construction, especially in downtown areas, can severely impact traffic flows. Either the traffic has to be rerouted during the entire period of construction at the expense of delays and denied access to properties, or temporary decking can be installed after the cut is made to allow restoration of traffic and reduce overall delay to motorists.

The general advantages and disadvantages of below-grade pedestrian systems and system elements is given in Table 3.

ADVANTAGES	DISADVANTAGES
. 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	. 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

TABLE 3

ADVANTAGES AND DISADVANTAGES
OF BELOW-GRADE SYSTEMS

Above-Grade Elements

Above-grade systems are those in which pedestrian movement occurs above the level of vehicular circulation. General advantages and disadvantages of the systems are given in Table 4. For the purpose of definition, five different types of elevated skyway, or walkway elements are described:

- independent,
- independent-flanking,
- integral-flanking,
- integral, and
- interior.

Each type is described in Figures 5 through 8. In addition, classification sublevels can be defined based on material, construction type and extent of covering. Due to the large number of possible combinations, however, these lower level elements will be defined as required in later chapters, in particular, see Chapter 3 on Facility Costs.

2.3 FACILITY IMPACTS

The provision of separate facilities for pedestrian circulation has several real and potential impacts on both facility users and non-users. The extent of these impacts depends upon the interaction of four basic sets of elements:

- facility design attributes,
- facility utilization,
- the magnitude and nature of first order benefits, and
- the magnitude and nature of second order benefits.

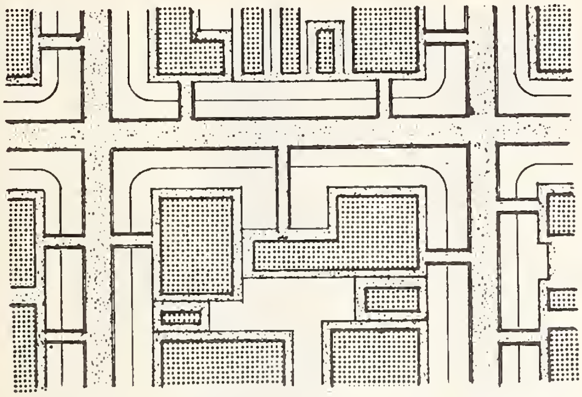
The diagrammatic interrelationship among the four sets of elements is shown in Figure 9. Solid lines represent strong relationships; dashed lines are for weaker, implicit influences.

Facility design attributes are those elements, inherent in the physical circulation system and/or facility, that encourage (or discourage) pedestrian activity and use of pedestrian-dominant pathways; this includes the accessibility of activity centers, directness and continuity of pathways, and similar factors. As shown in Figure 9, the design attributes influence the extent to which facilities are utilized by pedestrians. If they are not utilized, their

ADVANTAGES	DISADVANTAGES
. Separates pedestrian movement from vehicular movement	. Expensive to construct
. Can provide more direct, convenient paths for pedestrians	. Requires change-in-grade and numerous entry points
. Provide elevated visual vantage point	. Difficult and expensive to provide access into existing development
. Provide direct linkage of major activity centers	. Could diminish retail activity at the street level
. Can be built in increments and expanded into comprehensive system	. Coordination of property owners may be difficult to achieve
. Particularly applicable to new construction	. Elevated elements form areas at-grade that present security problems
. May utilize public rights-of-way linking and/or passing through existing buildings	. Difficult to coordinate to at-grade and below-grade transit systems
. Allows more compact and efficient arrangement of retailing space	. Creates potential danger of falling objects if not totally enclosed
. Improves at-grade vehicular circulation	. Adds to the already cluttered cityscape
. Provides cover for at-grade pedestrian movement	. Difficult to service for emergency, fire, security, etc.

TABLE 4

ADVANTAGES AND DISADVANTAGES
OF ABOVE-GRADE SYSTEMS

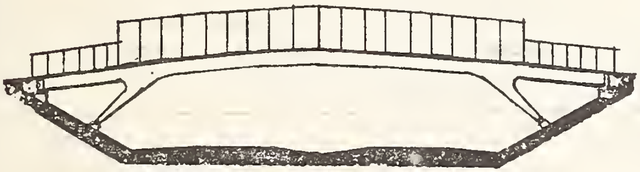


SKYWAY SYSTEM OVER STREET RIGHTS OF WAY

PLAN

Independent

SECTION



ELEVATION

PEDESTRIAN BRIDGE OVER MAJOR ARTERIAL

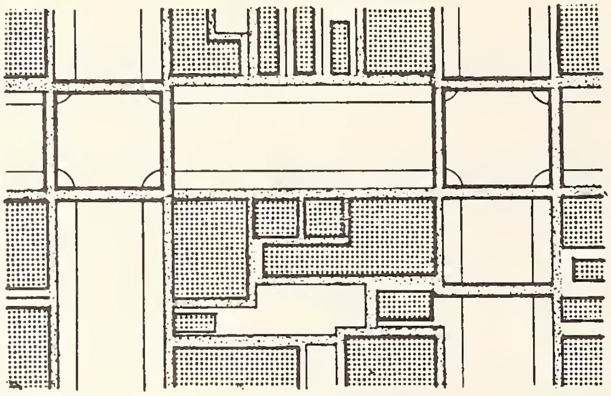
ELEVATION

ELEVATED WALKWAYS (INDEPENDENT)

Elements are self-supporting structurally and free-standing. Occur primarily at street crossings parallel to public rights-of-way, and at pedestrian bridges over major arterials.

FIGURE 5

DEFINITION AND EXAMPLES OF INDEPENDENT ELEVATED AND WALKWAY ELEMENTS



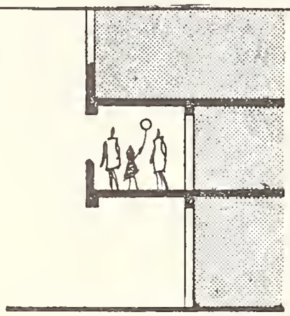
ELEVATED SKYWAYS (INDEPENDENT FLANKING)

PLAN

Independent-flanking

ELEVATED SKYWAYS (INDEPENDENT FLANKING)

This condition is defined as those portions of the walkway which are (1) self-supporting structurally and (2) adjacent to (flanking) building facades. This condition primarily occurs above sidewalks along public right-of-ways and adjacent to existing buildings along the second level walkway network. In such conditions, the walkway would usually be tied into existing structures at second level lobbies and, in the case of enclosure, the walkway enclosure bonnet would be received by the facade of the existing structures.



Integral

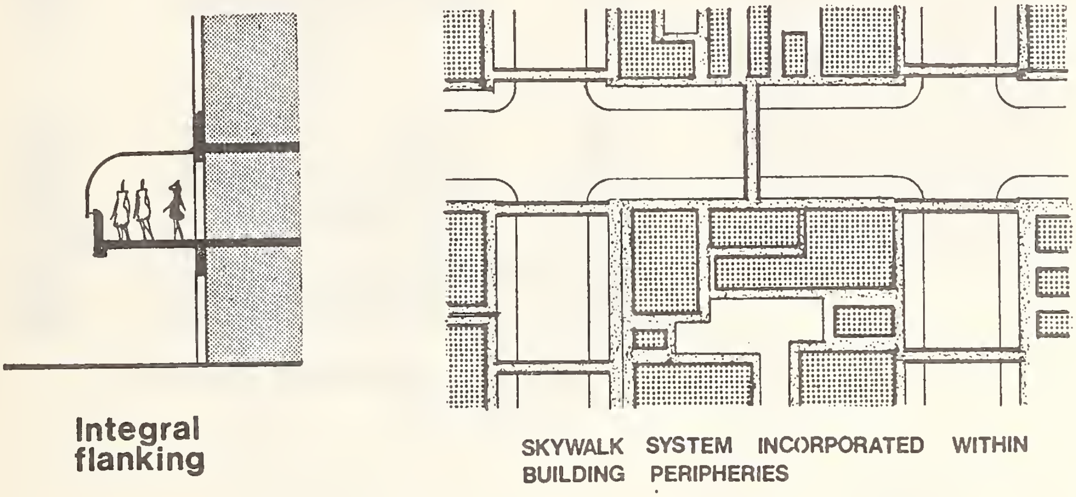
ELEVATED SKYWAYS (INTEGRAL FLANKING)

This condition is defined as those portions of the walkway which are (1) structurally integral with and (2) located along the building facade outside of the building envelope of new building developments. In this condition, the structure of the new development is extended or cantilevered out beyond the building envelope over the sidewalk to provide the elevated walkway.

FIGURE 6

SECTIONS

DESCRIPTION OF ELEVATED SKYWAYS - FLANKING CONDITIONS



SECTION

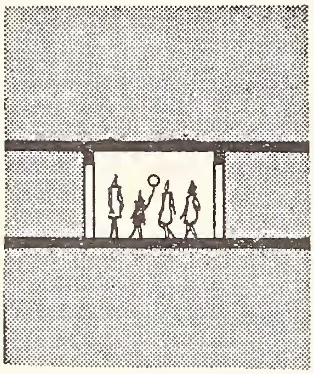
PLAN

ELEVATED WALKWAYS (INTEGRAL)

This condition is defined as those portions of the walkway which are (1) structurally integral with and (2) located along the building facade within the building envelope of new building developments along the walkway network. In this condition, the walkway would be planned, designed and built as part of the new development.

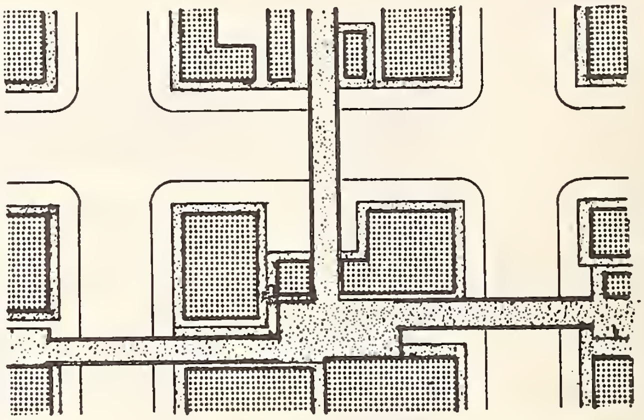
FIGURE 7

DESCRIPTION OF INTEGRAL ELEVATED WALKWAY ELEMENTS



Interior

SECTION



SKYWALK SYSTEM WITH MIDBLOCK CONNECTIONS

PLAN

ELEVATED WALKWAYS (INTERIOR)

This condition is defined as those portions of the walkway which are located within the interior of new developments and/or existing builings where the walkway network passes through a block rather than along street right-of-ways. In such cases, special legal provisions must be made to maintain the network as a public walkway or right-of-way within the development. This condition can also exist at-grade or below-grade

FIGURE 8

DESCRIPTION OF INTERIOR ELEVATED WALKWAY ELEMENTS

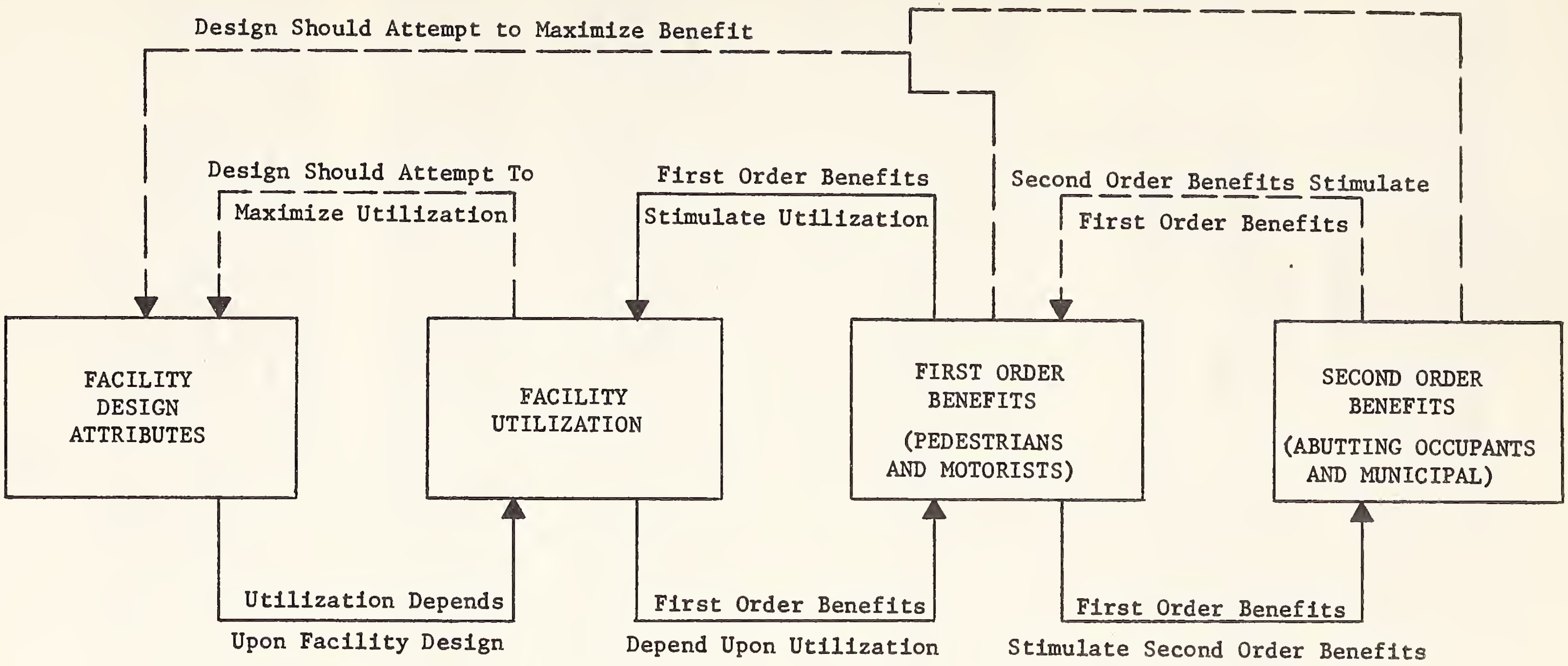


FIGURE 9

PEDESTRIAN FACILITY IMPACT DIAGRAM

impact is minimal. On the other hand, if they are highly utilized, then they give rise to a set of benefits to pedestrians in the form of increased safety, convenience and comfort. Pedestrian benefits, in turn, can induce benefits for non-users such as increasing the retail sales by abutting merchants and reducing vehicular delays.

However, the interaction of elements is even more complex. If the pedestrian does not perceive a benefit to himself from using the alternative facility, he will continue to use the vehicle-dominant paths. In this case, no added benefit accrues to him, and subsequent secondary benefits are not realized. Hence, the process has to start with a design that stimulates pedestrian utilization in order to achieve the resultant benefits.

Separate pedestrian paths must offer distinct and easily recognized benefits to the pedestrian. They must offer the pedestrian directness which will not result in time loss or greater distance. The paths must provide continuity of movement and possess adequate capacity. Vertical change requirements must be minimized and adequate vertical assistance provided where changes must be made. Protection against wind, rain, cold, heat and pollution will enhance utilization, as will the provision of security against criminal threat. Separation of pedestrians and vehicles is necessary to eliminate conflicts and provide safe pedestrian routes. The pathways should exhibit coherence so that pedestrian confusion and lack of orientation does not negate benefit. Adequate accessibility of the paths should be provided. Lastly, the pathway should offer a high level of aesthetics to stimulate pedestrian interest and psychologically reduce the negative effects of trip length and vertical change.

In addition to inducing movement on the facility pathways, steps should be taken, where appropriate, to discourage circulation on alternative routes. A prime example of this concept is the use of barriers to prevent pedestrians from crossing at-grade in the vicinity of pedestrian overpasses and underpasses.

As shown in Table 5, the pathway attributes of a pedestrian facility are directly related to pedestrian benefits. The facility impact on pedestrian safety is directly related to the extent of separation between people and vehicles provided. Pedestrian convenience depends on pathway directness, continuity, capacity and availability. Finally, the impact on pedestrian comfort is related to protection, coherence, security and visual image provided by the facility.

PEDESTRIAN BENEFITS	FACILITY PATHWAY ATTRIBUTES
SAFETY	SEPARATION
CONVENIENCE	DIRECTNESS CONTINUITY CAPACITY AVAILABILITY
COMFORT AND OTHERS	PROTECTION COHERENCE SECURITY INTEREST

TABLE 5

RELATIONSHIP BETWEEN PEDESTRIAN BENEFITS AND PATHWAY ATTRIBUTES

All the attributes listed are not necessarily independent of each other. For example, a coherent pathway provides comfort in that it relieves the anxiety of the lost or confused pedestrian; however, it may also avoid the necessity for backtracking and delays resulting from direction finding that could accompany being lost, and in this way impacts on pedestrian convenience. System accessibility is tied to the convenience of having alternative paths. Yet it may also impact on pedestrian comfort if the pathway is unavailable when needed during inclement weather. Since the degree of interdependency among the facility attributes remains to be determined, each one will be treated as a separate entity.

CHAPTER 3. FACILITY COSTS

3.1 THE GENERAL FACILITY COST APPROACH

The purpose of this chapter is to provide information on the costs of various types of pedestrian facilities. It is not intended to substitute for the detailed analysis of costs that would necessarily precede any large capital investment, but rather to provide a basis for comparison between alternative facility types and to establish a framework that will guide the development of estimates.

Two approaches to examining facility costs were considered. The first involves the tabulation of actual data collected from existing literature and specific sites together with descriptions of the elements affecting cost in each case. The second approach is the development of a basic cost estimating structure and, to the extent possible, the inclusion of actual component costs and cost estimating experience. Due to difficulties noted below, the second approach was selected and is described in the sections that follow. Actual costs are provided, where available, for the facilities cited in Chapter 8, and to a limited extent, in Chapter 7.

The difficulties of a direct extraction of existing facility cost data are primarily related to the following inconsistencies:

- In most cases, the costs associated with implementing pedestrian facilities are shared by several federal, state and local governmental agencies, and in some instances, the private sector. The combination of public and private expenditures or multiple funding makes it difficult to isolate the specific allocation and distribution of costs. In some cases, the public cost of these systems may be part of the total capital expenditures which are not broken out in detail.

- Where individual agency cost records related to facility construction are available, they are often maintained on a general or gross level. It is usually not clear what cost elements are included in these broad categories, or what the actual definitions are for the included costs.

- Different agencies use different unit cost dimensions (i.e., cost per square foot, cost per linear foot) for the same type of facility.

- Direct and indirect facility costs are not allocated on a consistent basis from location to location (e.g., the cost of public services may be included as a direct cost attributable to the facility in one place, but are not broken out from general cost accounts in other locales).

- Site-related contingencies that influence overall or elemental facility costs are extremely difficult to determine for each facility.

As a result of these shortcomings in the cost data available for specific sites, an approach was developed using a framework of cost elements together with a procedure for accumulating costs at various levels for the purposes of comparison. This approach, together with the cost figures provided, can also be used as a guide for developing preliminary cost estimates of specific proposed facilities. A diagram of the basic approach is shown in Figure 10. The sections where each component is discussed are noted at the bottom of the figure. Figure 11 shows the matrix which forms the computational framework for the procedural approach shown in Figure 10.

In the approach described in the following sections, basic facility characteristics and unit cost factors are used as input to a series of computational procedures to develop the capital cost of construction and the time stream of future operating and maintenance costs. Overall, this approach offers maximum flexibility, and serves:

- As a means to isolate those elements which contribute to the overall cost of a particular class of pedestrian facility for the purposes of cross-comparison and identification of those specific elements which represent either a cost savings or added expenditures; and

- As a cost estimating framework in which a pedestrian system can be defined, its individual sub-elements and associated impacts assigned a dollar value, and the total facilities cost computed.

This approach can further serve as a technique for evaluating or assessing the overall cost of competing alternative facility types.

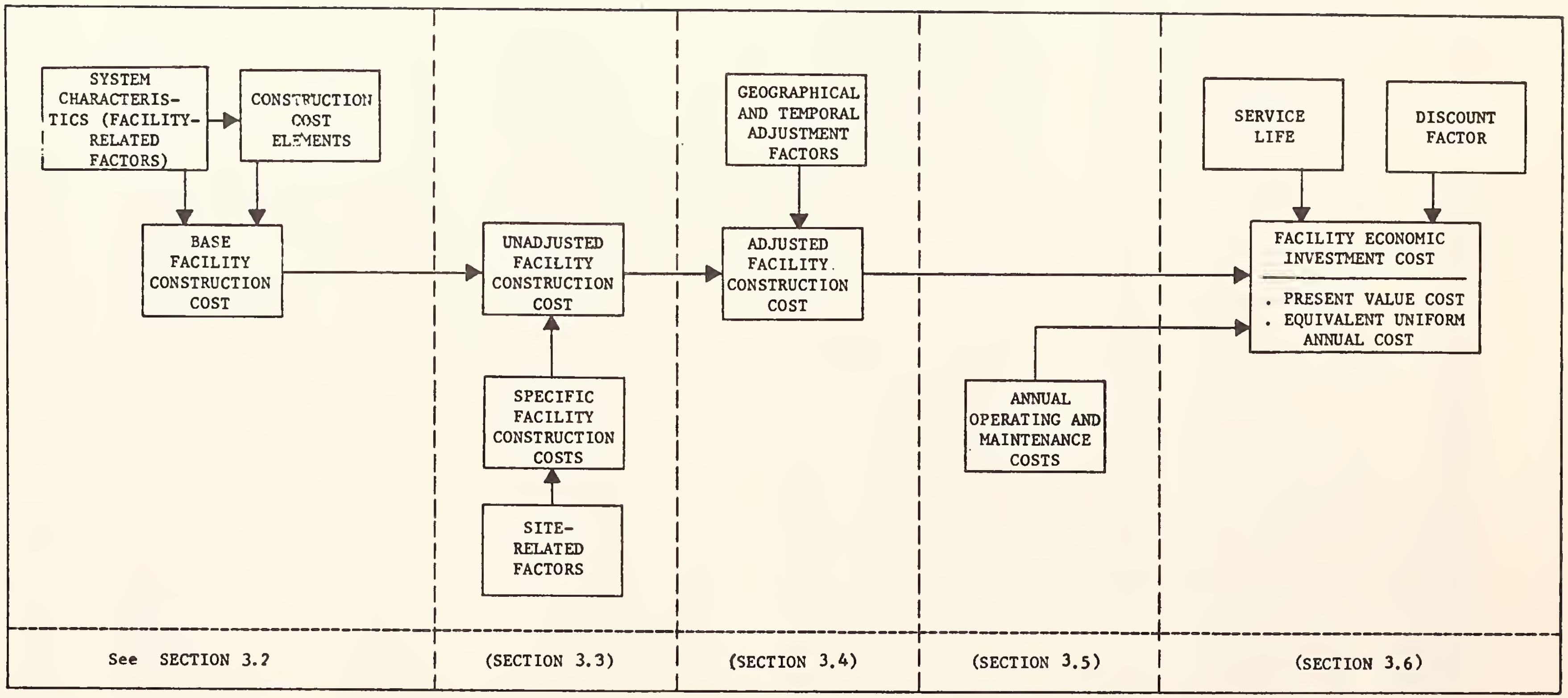


FIGURE 10

FACILITY COSTING APPROACH

The cost approach consists of five major steps which are described briefly below. These descriptions, together with Figures 10 and 11, provide an overview of the approach; more detailed descriptions are given in the sections that follow.

Step 1: Facility type, dimensional properties and similar system characteristics are used to isolate specific construction cost elements. These costs are then combined to obtain a base facility construction cost or "base cost". The base cost is related only to the cost of constructing the facility and does not reflect costs which are contingent upon the actual or proposed construction site. Cost elements provided in Section 3. 2. 3 are based on actual mid-1973 data.

Step 2: Characteristics of the facility site, such as foundation conditions and traffic delays due to construction are used to develop a set of site-specific facility construction costs. The specific costs are then added to the base cost computed in Step 1 to obtain the unadjusted facility construction cost.

Step 3: As required, the unadjusted facility construction cost will be modified using the appropriate factors to account for geographical and temporal differences in the data or to facilitate comparison with similar costs from other times or locations. The resultant cost will be called the adjusted facility construction cost. If annual operation and maintenance costs are minimal or can otherwise be ignored, then the adjusted cost will suffice for purposes of estimation and comparison. If this is not the case, Steps 4 and 5 are accomplished.

Step 4: The annual cost of facility operation and maintenance is computed. Due to the wide range of conditions and variability in the available data, only very rough guidelines are presented. The actual (estimated) costs are best computed using specific information for each proposed facility.

Step 5: Two basic and equivalent methods are presented for reducing current investment costs of construction and the future costs streams for facility operation and

FIGURE 11

COST FRAMEWORK

FACILITY CATEGORY	TYPE OF FACILITY/SYSTEM	SYSTEM CHARACTERISTICS																						— CONSTRUCTION COSTS
		DIMENSIONAL			STRUCTURAL						ENCLOSURE SYSTEM					ELEMENTS					MATLS. CONST. TECH.			
					SPAN			SUPPORT					ENCLOSED											
		WIDTH	HEIGHT	REQ. LENGTH	0–50'	50–100'	100'	AT TERMINALS ONLY	MULTISPAN	CONT. SUPPORTED	OPENED	COVERED	V	H	AC	LANDSCAPING	PAVING	STREET FURNITURE	LIGHTING	SIGNING	STEEL	CONC. POURED-IN-PLACE	CONC. PRECAST	
	ROADWAY CONFIGURATION →																							
1 HIGHWAY CROSSINGS	● PEDESTRIAN OVERPASS CONDITION 1–0																							
	CONDITION 1–1																							
	● PEDESTRIAN UNDERPASS CONDITION 1–0																							
	CONDITION 1–1																							
	CONDITION 1–2																							
	CONDITION 2–0																							
	CONDITION 2–1																							
	CONDITION 2–2																							
	CONDITIONS OF CARRIAGEWAY →																							
2 GRADE-SEP. SYSTEMS CBD	● PEDESTRIAN SKYWAY CONDITION 1–0 OPEN																							
	CONDITION 1–1 COVERED																							
	CONDITION 1–2 ENCLOSED																							
	● PEDESTRIAN SUBWAY CONDITION 1–0 NEW ROADWAY																							
	CONDITION 1–1 EXISTING ROADWAY CUT & COVER																							
	CONDITION 1–2 TUNNELED UNDERPASS																							
3 AT GRADE SYSTEMS IN CBD	HORIZONTAL DISPLACEMENT																							
	● PEDESTRIAN MALL CONDITION 1–0																							
	● PARTIAL PEDESTRIAN MALL CONDITION 2–0																							

FIGURE 11 continued

SPECIFIC (SITE RELATED) COST IMPACT VARIABLES																					ADDITIONAL COST OF LOCATIONAL CONTINGENCIES SUBTOTAL II II	UNADJUSTED FACILITY CONSTRUCTION COST SUBTOTAL I & II I + II	TEMPORAL ADJUSTMENT FACTOR (INFLATION)	GEOGRAPHIC ADJUSTMENT FACTOR	ADJUSTED FACILITY CONSTRUCTION COSTS III	MAINTENANCE/ OPERATING COSTS (WHERE APPLICABLE) IV	FACILITY INVESTMENT COST V
FOUNDATION CONDITIONS				UTILITIES RELOCATION						TERMINAL CONNECTIVITY					STRUCTURAL			TRAFFIC OPER.									
POOR SOIL N. FOUND PILES	WATER PUMPING/ DEWATERING	EXCAVATION (ROCK, ETC.)	UNDERPINNING	PHYSICAL RELOCATION			SUPPORT AND PROTECTION			STAIRS	RAMPS	ESCALATORS	ELEVATORS	OTHER	SHORT SPAN 0–50'	LONG SPAN 50–100'	100'	RE ROUTING STREET CLOSING	CONSTRUCTION IMPEDANCE	OTHER							
				H	M	L	H	M	L																		

maintenance to a single value so that comparisons can be made. This final figure is called the facility economic investment cost.

Each step in the procedure introduces additional cost elements that contribute to overall facility cost. In general, comparisons between alternative systems or between costs and benefits are valid only after Step 5 using methods similar to those described in Section 3. 6. In too many cases, engineering estimates take into account only those elements related to the facility and ignore site contingent costs, temporal effects or continuing operating and maintenance costs. This is equivalent to using the output of Step 1 which may result in the acceptance of invalid conclusions. Particular care has to be exercised when using average costs since they often exclude the effects of those site-specific costs introduced in Step 2 of the above approach. As a minimum, the procedure should be carried through Step 2 before any comparisons are made, and then only if it is clear that the other cost elements can be disregarded without prejudicing the study results.

Disregarding the effects of time and geography, the construction cost of a pedestrian facility is a function of two sets of variables or factors:

- Facility-related factors which reflect characteristics of the facility itself such as material used or type of enclosure system provided, and

- Site-related factors that are characteristic of the facility location such as extent of utility relocation or traffic interruptions required.

The two sets of factors are used to develop two costs which, when combined, constitute the unadjusted facility construction cost. The first set is used to compute the basic facility construction cost as described in Section 3. 2, and the second set is used to calculate the specific facility construction cost as discussed in Section 3. 3. The purpose of dividing the factors that influence facility costs into two groups is to isolate those cost elements which, for the most part, relate only to the facility structure; these costs are transferable and can be estimated and applied over a broad range of conditions. The second set of factors relate to cost elements that will change from site to site and, in general, have to be determined to suit each situation.

3.2 THE BASIC FACILITY CONSTRUCTION COST

3.2.1 Factors Influencing Base Cost

The facility construction cost, unadjusted for any effects of time or geographical location and disregarding any costs specifically related to the site or site preparation, will be called the basic facility construction cost or more briefly the base cost. The base cost can be computed as the product of two elements:

- The unit cost of construction, i.e., the cost per square foot, the cost per lineal foot or similar measure, and
- The number of construction units (square feet, lineal feet) consistent with the unit cost figure.

Both the unit cost and the number of units are functions of several other factors as shown in Table 6 and discussed in the sections that follow.

- FACILITY TYPE
- DIMENSIONAL PROPERTIES
- STRUCTURAL PROPERTIES
- MATERIAL AND CONSTRUCTION METHOD
- ENCLOSURE SYSTEM; AND
- SUB-ELEMENTS

TABLE 6

FACILITY-RELATED FACTORS THAT INFLUENCE BASE COST OF CONSTRUCTION

3.2.2 Facility-Related Factors

Facility Type

Base construction costs will obviously vary by the type of facility since it affects the unit cost of construction, and will also affect the dimensions used to determine the number of construction units. Specific facilities are discussed in detail in Chapter 2; for the purpose of costing, the following generic facility types will be considered:

- Highway overpasses (pedestrian bridges);
- Street and highway underpasses (pedestrian tunnels);
- Elevated Skyways; and
- Full and partial at-grade malls.

Dimensional Properties

The height, width and length dimensions of a specific facility will determine the number of construction units, and will also impact on facility support costs and several of the specific site-related costs discussed in Section 3. 3.

Structural Properties

The important structural properties to be addressed are:

- length of clear span; and

- method of facility support (superstructure).

The per unit construction cost of a section of facility will increase as a function of the length of clear span. For purposes of cost analysis, spans of 40, 80 and 120 feet are considered. Various span lengths require systems of support that occur at different spatial intervals, or continuously depending on the facility type. Hence, the length of clear span together with the method of support are factors that influence the base cost.

Material and Construction Method

Probably the most dominant factors that influence the base cost of construction for a given facility type are those related to material and construction method used. The first four combinations described below are used to develop cost factors in Section 3. 2. 3. The others are included for completeness, but are not used to develop costs due to difficulties in generalizing their application.

(1) Steel - Prefabricated steel truss members, assembled off site, delivered to the site and subsequently erected. This would include by definition vierendeel (vertical and horizontal members only) or conventional triangulation systems; see Section 3. 2. 3 on skyway costs;

(2) Steel - Standard steel construction, steel rolled and shop fabricated, all connections and joinings are erected in-place on site.

(3) Concrete - Cast-in-place - using conventional reinforced framing the concrete is cast-in-place on site. This would include beam and slab, one way joists, or waffle construction systems.

(4) Concrete - Pre-cast - pre-stressed members and piers are prefabricated off site, then delivered to the site for erection. This would include by definition single or double "T" sections up to 65 feet in length by 8 feet in width.

(5) Concrete - Cast-in-place - post-tensioned. High strength strands are used which are stressed to place the concrete in compression prior to the application of service loads.

(6) Composite construction - The use of steel and concrete together. This construction is normally performed in-place on site.

There are also other methods of construction which involve the use of concrete or steel arches, and systems involving the use of suspension cables. However, from an economic standpoint these systems are considered to be impractical.

The cost factors given in Section 3. 2. 3 are based on the ready availability of both material and construction expertise related to each of the options defined above. A secondary level of cost-influencing factors may have to be considered if either of these resources is constrained. The following factors may be present and could impact on the unit cost of construction:

- Geographical or regional material supply characteristics;
- Scarcity of supply resulting in long delivery times and possible delays;

- Location of suppliers relative to construction site; and
- Availability of expertise in specific construction techniques (i.e., prefabricated steelwork).

Enclosure System

The type of enclosure and mechanical support systems provided have a substantial impact on the basic cost, particularly for enclosed systems where the requirement for climate control can double or triple costs per lineal foot.

The following alternatives are considered:

- open - no enclosure.
- covered - system is covered but not enclosed from the weather.
- enclosed - system is fully enclosed and employs one of three types of climate control;
  - naturally ventilated,
  - heated only, or
  - heated and airconditioned.

Sub-Elements

This last group of factors includes those miscellaneous elements that impact on base cost such as lighting, signing and landscaping. In some cases, amenities such as landscaping, street furniture, fountains, and the type of walkway paving or finish may be important. Because the costs related to these elements depend to a large extent on quality as well as quantity, direct specification of their impacts for comparison or estimation purposes is difficult. Where it is necessary to include these elements, careful and detailed consideration of their cost impact should be analyzed.

3.2.3 Facility Construction Cost Elements

In this section, cost elements are provided for various facility types. An attempt has been made to cover a wide range of alternative possibilities. It has been necessary, however, to make basic assumptions on dimensions, spans and other variables in order to reduce the unlimited number of combinations to a reasonable subset for presentation. These assumptions are specified for each facility type. Costs are shown to the nearest five in the third significant digit.

Highway Overpasses

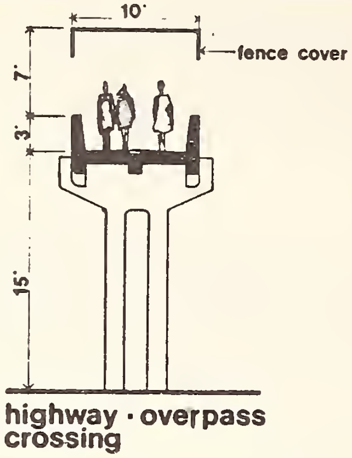
Table 7 contains the elemental cost information necessary to estimate the base cost of construction for highway overcrossings (pedestrian bridges). Basic assumptions relating to the highway crossing are detailed in Figure 12.

(1) UNIT COST OF AERIAL STRUCTURE									
Material/ Construction	Conventional Steelwork (cased)			Conventional Concrete/Cast in Place			Concrete/Precast		
Length of Clear Span (feet)	40	80	120	40	80	120	40	80	120
Cost per Lineal Foot ($)	345	380	400	215	245	270	225	260	280
(2) OTHER COSTS									
Drainage	Add $16 per lineal foot								
Lighting	Add $28 per lineal foot								
Pier	Add $2,420 for each pier								
Median Strip (30' x 8')	Add $1,200 for each median								

TABLE 7

ELEMENTAL CONSTRUCTION COSTS FOR
HIGHWAY OVERPASSES
(TWELVE FEET WIDE OVERALL)

The unit cost per lineal foot as a function of material, construction and span is first determined for each bridge section. The costs of lighting and drainage are added accordingly. These costs



SECTION

DIMENSIONAL PROPERTIES

ASSUMPTIONS:

(1) AERIAL STRUCTURE

- 12-15 foot width overall
- Varying depth edge beams/side walls dpending on span
- Protective screening (fencing cover) provided to serve as safety covering
- Lighting and drainage are costed separately
- Cost varies with finishing materials, construction and span

(2) PIERS

- 15 foot high cast-in-place concrete
- 2 foot wide at terminal of overpass
- Median strip, if required, costed separately

(3) MEDIAN STRIP

- 30 x 8 foot median
- Concrete with curbing and guard rails

FIGURE 12

ASSUMPTIONS REGARDING COSTS OF HIGHWAY OVERPASSES are then multiplied by the appropriate lineal feet of construction and summed to obtain the base cost of the aerial structure. The cost of piers and median strips are then added using the cost-per-unit figures given.

Street and Highway Underpasses

The unit costs for street and highway underpasses (pedestrian tunnels) are given in Table 8. Assumptions are given in Figure 13. Note that condition (1) is applicable to underpasses constructed during roadway construction; the other two conditions are for existing roads or streets.

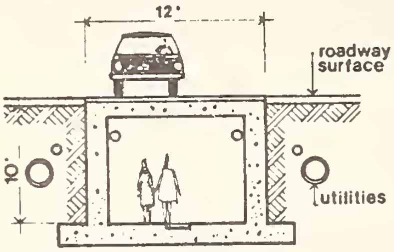
CONDITION	$ PER LINEAL FOOT
(1) Cut and Cover Construction, No Restriction	780
(2) Cut and Cover Construction With Street Decking to Maintain Traffic Flow	1,170
(3) Tunnelled Underpass, Cast-In-Place Concrete	2,040

TABLE 8

UNIT CONSTRUCTION COSTS FOR HIGHWAY UNDERPASSES

Elevated Skyways

Elevated skyways are similar to highway overpasses in terms of their method of costing. The unit cost is dependent on material, construction and span. Enclosure costs are also functions of facility length. The cost of piers must be added to the base cost of the skyway structure. Cost elements for conventional steel and concrete skyways are given in Table 9, and related assumptions are given in Figure 14. Skyways of trussed steel construction are a special case of skyways; costs per square foot for spans of 80 feet or less are given in Table 10.



highway · underpass crossing

SECTION

DIMENSIONAL PROPERTIES

ASSUMPTIONS:

(1) CONDITION 1 - BUILT IN CONJUNCTION WITH NEW ROADWAY CONSTRUCTION

- Concrete, continuously supported
- 12-15 feet wide by 10 feet high, minimum length of 80 feet
- Natural ventilation (for lengths < 200 feet)
- Lighting and drainage cost included
- Normal cut and fill excavation (rock and other foundation problems will incur extra cost as detailed in Section 3.3)

(2) CONDITION 2 - BUILT UNDER EXISTING ROADWAY

- Same as condition 1 except that added costs are incurred to remove road (street) surface and provide decking to maintain traffic flow

(3) CONDITION 3 - TUNNEL UNDER EXISTING ROADWAY

- Same as condition 1, except costs reflect tunnel excavation including normal shoring and cast-in-place concrete
- Traffic flow is unimpeded

FIGURE 13

ASSUMPTIONS REGARDING COSTS OF STREET AND HIGHWAY UNDERPASSES

(1) SKYWAY ONLY				
Material/ Construction	Conventional Steel (cased)		Conventional Concrete/Cast-in-Place	
Length of Clear Span (feet)	40	80	40	80
Cost per Lineal Foot ($)	320	356	190	215
(2) ENCLOSURE SYSTEM				
(a) Covered, not enclosed	Add $60 per lineal foot to (1)			
(b) Enclosed, heated only	Add 620 per lineal foot to (1)			
(c) Enclosed, heated and air conditioned	Add 735 per lineal foot to (1)			
(3) PIER	Add $3,950 for each pier			

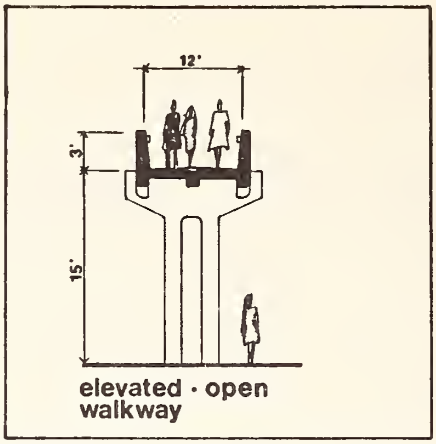
TABLE 9

ELEMENTAL CONSTRUCTION COST FOR ELEVATED SKYWAY SYSTEMS

CONDITION	$ PER SQUARE FOOT
(1) Structure only including decking	98
(2) Totally enclosed and air conditioned	170

TABLE 10

UNIT COSTS FOR STEEL TRUSSED CONSTRUCTED SKYWAYS (SPANS OF 80 FEET OR LESS)



SECTION

DIMENSIONAL PROPERTIES FOR OPEN SKYWAYS

ASSUMPTIONS:

(1) AERIAL STRUCTURE

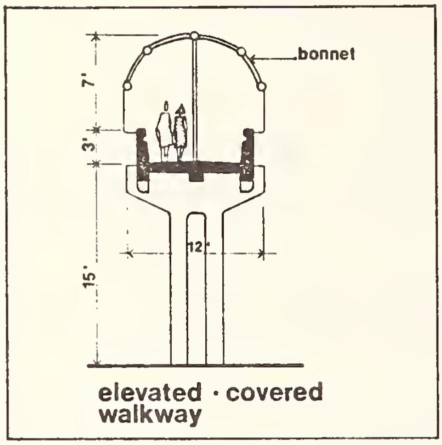
- Cost varies by material/construction and span
- Includes costs of lighting, drainage and handrails
- Spans are 0' - 40' and 40' - 80'

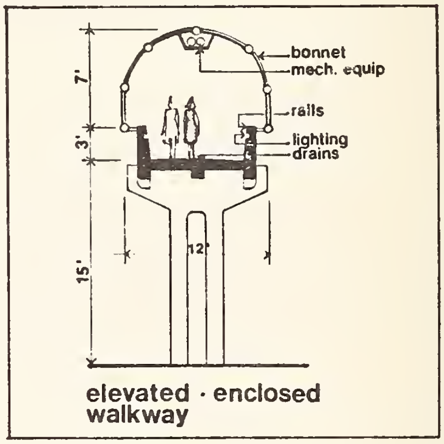
(2) SUPERSTRUCTURE (PIER)

- Concrete, cast-in-place, includes footing
- 15 feet high, with 2-foot wide section
- Applies to all enclosure types

(3) ENCLOSURES

- Sectional dimensional properties





covered

- Bonnet is aluminum tubing frame with 1/4" tinted plexiglass

enclosed

- heated only
- heated and air conditioned

FIGURE 14

ASSUMPTIONS REGARDING ELEVATED SKYWAY SYSTEMS (CONVENTIONAL STEEL AND CONCRETE STRUCTURES ONLY)

CATEGORY	1/ Quantity and units		Unit Cost	Total Cost ($)	
	PARTIAL MALL	FULL MALL	($)	PARTIAL MALL	FULL MALL
A. SITE PREPARATIONS					
1. Removal of sidewalk paving	450 sy	800 sy	4.47/sy	$ 2,012	$ 3,576
2. Removal of curbing	800 lf	800 lf	2.14/lf	1,712	1,712
3. Removal of street paving surface	700 sy	1,500 sy	4.84/sy	2,905	6,225
4. Utilities relocation	Allow		9.20/cy	784	1,567
B. NEW CONSTRUCTION					
1. Curbing (concrete)	950 lf	1,400 lf	9.50/lf	9,025	13,300
2. Paving: concrete or brick (inc. line painting)	11,000 sy	19,000 sf	2.10/sf	23,100	39,900
3. Planters/containing walls (1'x2' high)	200 lf	800 lf	18.50/lf	3,700	14,800
4. Lighting					
a. street lights	10 fix.	10 fix.	575/fix.	5,750	5,750
b. accent (wall type)	100 lf	500 lf	15.50/lf	1,550	7,750
5. Stairs	100 lf	200 lf	23.14/lf	2,314	4,628
C. LANDSCAPING					
1. Trees - small	25 s	40 s	67.00/ea	1,675	2,680
- large	45 l	45 l	98.00/ea	4,410	4,410
2. Ground cover (planting)	4,000 sf	8,000 sf	2.80/sf	11,200	22,400
D. STREET FURNITURE					
1. Benches (concrete)	300 sf	900 sf	44.00/sf	13,200	39,600
2. Mail boxes/trash rec. etc. units	10	10	300/ea	3,000	3,000
3. Fountains/water surfaces, pools, etc.	100 sf	500 sf	72.00/sf	7,200	36,000
4. Kiosks-wood and canvas, steel tubed (10'x10'x10')	2	5	1,000/ea	2,000	5,000
5. Tree gradings	20	40	200/ea	4,000	8,000
E. SIGNING inc. posts and frames installation	6	12	500/ea	3,000	6,000
F. BUS SHELTERS OR COVERINGS FOR ARCADES	150 lf	400 lf	125/lf	18,750	50,000
TOTAL COSTS				$119,737	$276,298

1/ For estimating purposes, quantities used are averages for malls actually completed in 15 cities.

TABLE 11

EXAMPLE OF COSTS FOR FULL AND PARTIAL AT-GRADE MALLS

Full and Partial At-Grade Malls

In cases where at-grade malls are viable alternatives to elevated walkways or below-grade street crossings, the cost data shown in Table 11 will be useful for comparative purposes. Care should be taken since malls exhibit a wide degree of cost variability depending on the quality and magnitude of landscaping and street amenities, the extent of below grade modifications, and so on; appropriate allowances should be made for these special features. The summarized breakdowns in Table 12 are useful for more general estimating purposes. (See Section 8.4.3 for a case study describing the costs associated with well-known Nicollet Mall in Minneapolis, Minnesota.)

COST CONTRIBUTING CATEGORY	PARTIAL MALL % OF TOTAL COST	FULL MALL % OF TOTAL COST
Site Preparation	5.8	4.
General Construction	36.6	31.4
Landscaping	14.1	10.4
Street furniture	26.0	32.5
Signing	2.5	2.2
Bus shelters	15.0	18.7
TOTAL	100.0	100.0

TABLE 12

CATEGORICAL PERCENTAGE COST BREAKDOWN RELATIVE TO TOTAL COST FOR FULL AND PARTIAL MALLS

3.2.4 Computation of Base Construction Cost

The equations for computing the base facility construction costs for the facility types examined are given in Figures 15 through 18. All costs are computed using the cost buildup approach shown in Table 11.

C_0 = BASE CONSTRUCTION COST OF HIGHWAY OVERPASSES

$$= \left[\sum_{\text{ALL SPANS}} \begin{pmatrix}\text{LENGTH OF}\\ \text{SPAN IN}\\ \text{LINEAL}\\ \text{FEET}\end{pmatrix} \times \begin{pmatrix}\text{COST PER LINEAL}\\ \text{FOOT (depending}\\ \text{on material, con-}\\ \text{struction \& span)}\end{pmatrix} \right]$$

$$+ \left\{ \begin{pmatrix}\text{TOTAL FACILITY}\\ \text{AERIAL LENGTH}\\ \text{IN FEET}\end{pmatrix} \times \left[\begin{pmatrix}\text{COST PER}\\ \text{LINEAL FOOT OF}\\ \text{DRAINAGE, IF}\\ \text{APPLICABLE}\end{pmatrix} + \begin{pmatrix}\text{COST PER}\\ \text{LINEAL FOOT OF}\\ \text{LIGHTING, IF}\\ \text{APPLICABLE}\end{pmatrix} \right] \right\}$$

$$+ \left[\begin{pmatrix}\text{COST}\\ \text{PER}\\ \text{PIER}\end{pmatrix} \times \begin{pmatrix}\text{NUMBER OF}\\ \text{PIERS}\\ \text{REQUIRED}\\ \text{See Note 1}\end{pmatrix} \right] + \left[\begin{pmatrix}\text{COST}\\ \text{PER}\\ \text{MEDIAN}\end{pmatrix} \times \begin{pmatrix}\text{NUMBER OF}\\ \text{MEDIANS}\\ \text{REQUIRED}\\ \text{See Note 2}\end{pmatrix} \right]$$

Note 1: The Number of Piers Required is [2x(No.of Spans)]

Note 2: The Number of Medians Required is [No. of Spans - 1]

FIGURE 15

COMPUTATION OF THE BASE CONSTRUCTION COST FOR HIGHWAY OVERPASSES

C_U = BASE CONSTRUCTION COST OF STREET AND HIGHWAY UNDERPASSES

$$= \left[\begin{pmatrix}\text{LENGTH OF}\\ \text{FACILITY IN}\\ \text{FEET}\end{pmatrix} \times \begin{pmatrix}\text{COST PER LINEAR FOOT}\\ \text{DEPENDING ON CONDITION}\\ \text{See Table 8}\end{pmatrix} \right]$$

FIGURE 16

COMPUTATION OF BASE CONSTRUCTION COST FOR STREET AND HIGHWAY UNDERPASSES

$$C_E = \begin{array}{l}\text{BASE CONSTRUCTION COST FOR CONVENTIONAL STEEL AND}\\ \text{CONCRETE ELEVATED WALKWAYS}\end{array}$$

$$= \left[\sum_{\substack{\text{ALL}\\ \text{SPANS}}} \left(\begin{array}{c}\text{LENGTH OF}\\ \text{SPAN IN}\\ \text{FEET}\end{array}\right) \times \left(\begin{array}{c}\text{COST PER LINEAL FOOT}\\ \text{DEPENDING ON MATERIAL,}\\ \text{CONSTRUCTION AND SPAN}\\ \text{See Figure 21}\end{array}\right)\right]$$

$$+ \left[\left(\begin{array}{c}\text{TOTAL}\\ \text{LENGTH OF}\\ \text{FACILITY IN}\\ \text{FEET}\end{array}\right) \times \left(\begin{array}{c}\text{COST PER LINEAL FOOT}\\ \text{OF ENCLOSURE SYSTEM}\\ \text{DEPENDING ON TYPE}\\ \text{See Figure 21}\end{array}\right)\right]$$

$$+ \left[\left(\begin{array}{c}\text{COST}\\ \text{PER}\\ \text{PIER}\end{array}\right) \times \left(\begin{array}{c}\text{NUMBER OF}\\ \text{PIERS REQUIRED}\\ \text{See Note}\end{array}\right)\right]$$

Note: Number of Piers Required is [2x(No. of Spans)]

FIGURE 17

COMPUTATION OF BASE CONSTRUCTION COST FOR CONVENTIONAL STEEL AND CONCRETE ELEVATED SKYWAYS

$$C_S = \text{BASE CONSTRUCTION COST FOR STREEL TRUSSED SKYWAYS}$$

$$= \left(\begin{array}{c}\text{FACILITY}\\ \text{AREA IN}\\ \text{SQUARE FEET}\end{array}\right) \times \left(\begin{array}{c}\text{COST PER SQUARE}\\ \text{FOOT DEPENDING ON}\\ \text{ENCLOSURE CONDITION}\\ \text{See Table 10}\end{array}\right)$$

FIGURE 18

COMPUTATION OF BASE CONSTRUCTION COST FOR STEEL TRUSSED SKYWAYS

3.3 SITE-SPECIFIC FACILITY CONSTRUCTION COSTS

The construction cost of a facility will often depend on a great number of variables that are related to the specific site at which the facility is to be constructed. These variables were purposely eliminated in the previous section where the intent was to derive a base construction cost that was dependent upon factors associated with the facility itself, but independent of the cost contingencies related to the facility site. In this section several of the site-related factors that influence cost are discussed. No attempt has been made to delineate every site-specific cost contingency, but rather to detail those that tend to dominate or greatly influence total construction cost, or those such as the cost of traffic delays during construction which are often overlooked in economic analyses of proposed facilities. Also, it would not be practical in all instances to provide point estimates of various site-related costs due to their associated variance, and hence, some values are given instead as reasonable ranges. The following factors are discussed in subsequent sections:

- Foundation conditions;
- Utilities relocation;
- Terminal connections;
- Structural considerations; and
- Traffic delays during construction.

3.3.1 Foundation Conditions

An important site-related factor is the condition of the soil and the requirements necessary to prepare the soil to receive the facility's substructure. A substantial range of additional facilities costs are the direct result of the poor supporting characteristic of soils, the elevation of the water table, the existence of rock, and the necessity to excavate in proximity to existing superstructure. Each of these conditions is site specific and result in additional costs due to unusual construction requirements; Table 13 provides estimated cost impacts of various conditions in most cases. Where these conditions exist, below-grade facilities are not always feasible.

3.3.2 Utilities Relocation

Especially when pedestrian systems are being proposed in urbanized areas, consideration must be given to the existence of various below-grade utility lines and conduits that may be affected by the path of the facility's construction. These utilities (water, gas,

CONDITION	CONSTRUCTION REQUIREMENTS	ADDED COSTS
Rock	Special Excavation Equipment	$10-20 per Cubic Yard
Elevation of Water Table	Dewatering or Pumping	$4.50-6.50 per Cubic Yard
Poor Supporting Characteristics of Soil	Installation of Piles or Employment of Mat Foundations	$220 per Pile
Close Proximity to Existing Buildings	Underpinning (Excavating Sheeting)	$100-130 per Cubic Yard

TABLE 13

EXAMPLES OF ADDED CONSTRUCTION COSTS RESULTING FROM SITE FOUNDATION CONDITIONS

electric, telephone, etc.) may require relocation, replacement and upgrading depending upon both their location and their condition. In addition to physical relocation, existing utility lines may need to be supported and protected from new construction; these lines may have to be encased and/or shored throughout the course of construction to guard against possible breakage even though they are not directly in the way of the facility.

The range of costs associated with utilities relocation is extreme. Cost allowances per cubic yard of excavation due to utilities can range from $8.75/cy to $15.00/cy. This cost can contribute an additional 30 to 200 percent to base construction costs. In Toronto, under-street crossings for a 20-foot right-of-way are estimated to cost between $1600 per lineal foot where utility problems are minimal to $4500 per lineal foot where utility problems are severe.(1) (See Section 8.4.2.) The possibility of routing below-grade walkways to avoid utilities should be considered. In Winnipeg, a below-grade system was estimated to cost $7 million due to severe conflict with existing underground utilities, but by a unique configuration of the system, walkways were re-routed to avoid utilities with a resulting $4.5 million savings--thereby making the below-grade system cost comparable with a proposed $2.5 million above-grade alternative.(2)

3.3.3 Terminal Connections

Each grade-separated system requires one or more terminal connections for the purpose of linking the system to the at-grade pedestrian access network. A variety of frequently used terminal connections have been identified in Figure 19, including stairs, ramps, elevators and escalators. The selection and use of any or all of these connectors is contingent upon several factors:

(1) The total vertical difference between the elevation of the system at the point of desired accessibility,

(2) Pedestrian volumes at the access and egress portals,

(3) Type of node in terms of activity linkage,

(4) The capacity characteristics in terms of volumes of pedestrians through an area in a given period of time, and

(5) Population characteristics considering proportion of elderly, handicapped.

The net addition to the base cost of any particular system is determined by adding the cost resulting from the use of particular terminal or intermediate connectors.

Representative assumptions and related costs for the four types of connections are given in Figure 19.

Terminal connections are considered as site-related considerations, since the physical situation will often dictate the type of connection system employed. Also, if additional right-of-way acquisition costs are incurred due to placement of terminals, these costs should be added to the construction cost of the facility.

3.3.4 Structural Considerations

Several structural considerations, namely spanning distance and method of support, were addressed in the development of base

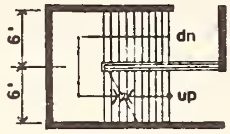
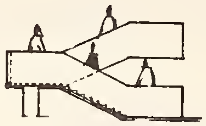
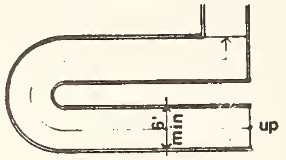
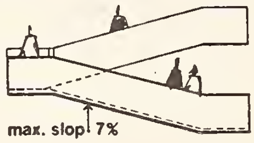
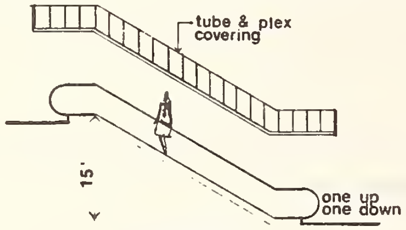
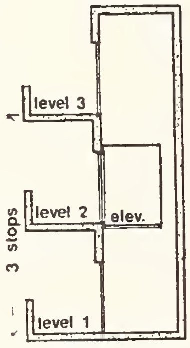
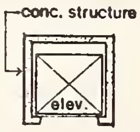
CONNECTION	DESCRIPTION	TOTAL COST
STAIR	 PLAN  SECTION Width of run is 6 feet; connect grade to 15 feet minimum; costs of concrete structure, enclosure walls, rails and lighting included.	$ 9,620 Per Unit
RAMP	 PLAN  SECTION Width of run is 6 feet; connect from grade to 15 feet minimum; maximum slope is 7%; costs of concrete structure, enclosure walls, rails and 1 lighting included.	$ 13,170 Per Unit
ESCALATOR	 SECTION One pair (up/down) from grade to 15 feet; cost includes units, enclosure structure and covering.	$120,000 Per Pair (Unit)
ELEVATOR	 SECTION  PLAN One cab (capacity 3000 lbs.) to stop at three levels; cost includes elevator and housing structure.	$ 38,000 Per Unit

FIGURE 19

TYPICAL TERMINAL CONNECTIONS AND COSTS

facility costs in Section 3.2. The consideration and selection of a structural system is also contingent upon several locational factors, such as the following:

- length to be spanned unsupported;
- whether or not it is feasible to locate intermediate pier supports in medians within the road right-of-way; and
- the compatibility of the structure with ambient environmental and architectural characteristics.

In the case of skyway and elevated walkway construction, there are added costs associated with increasing unsupported span lengths which must be weighed against additional costs associated with superstructure (cost of providing supporting piers at varying intervals), as well as the cost of median construction which may in turn result in construction impedance to traffic flow and operations. The location of elevated systems relative to buildings is also an important determinant in the selection of a structure; whether the system ties into existing or new buildings, or is free standing and has no direct connection to abutting properties, largely determines the span and support characteristics of the structure, and hence, the cost of constructing the system.

3.3.5 Traffic Delays During Construction

The construction of any pedestrian facility built either within, above or below a vehicular right-of-way will normally require alteration or modification to the flow of vehicular traffic either permanently, or temporarily during the period of the facility's construction. The costs of permanent street or lane closings must be determined in terms of changes in the overall traffic network and movement caused by the proposed facility. Temporary street closings, lane blockage, detours and rerouting, on the other hand, caused by construction of other types of pedestrian facilities generally result in vehicular delays during construction. The costs of these delays to vehicles represents a cost that is attributable to the facility construction, but one that is often overlooked.

The actual cost of delay will depend on factors such as:

- Number of vehicles and traffic lanes affected by the construction per unit time;

- Average delay time per vehicle;
- Excess cost of vehicle operation due to speed reduction and idling per delayed vehicle;
- Value of vehicle time per unit time; and
- Duration of construction.

These factors can be used to compute the increased cost of vehicle operation and vehicle delay resulting from the construction. The methods parallel those used in Chapter 7 to compute the cost of pedestrian-related delay costs.

The last factor listed above, the total time over which construction delays vehicles, can be controlled to reduce the impact of delay. The use of precast or prefabricated members, for example, results in longer allowable spans, reduced depth of structure and increased speed of erection. Hence, while prefabrication is being done at a location off-site, on-site preparation can be accomplished concurrently since they are independent of each other. The net result is a considerable time savings in the overall construction process, as well as in the on-site erection.

In other situations, it may be impractical (i.e., in active and dense urban areas) to store construction materials and equipment necessary for on-site construction in the immediate proximity of the facility location. When this happens, the storage or movement of materials and equipment can cause measurable traffic delays during the construction period which should be considered. Again, use of off-site prefabrication may help to alleviate this problem.

Table 14 provides a simple relationship between material/ construction type and time required to erect on-site. The actual extent of construction delays will depend on numerous other factors, but all things being equal, the impact of the construction technique employed will be as shown.

A more detailed estimate of construction time for individual <u>unit</u> items would be possible, but it would not give an accurate reflection of a construction schedule based upon a <u>project</u> using a varied number of different units. Timing is best assessed after a project has been put together, and it will be dependent upon a number of variable factors such as location, complexity of design, availability

TYPE OF CONSTRUCTION TECHNIQUE	TIME REQUIRED TO ERECT FACILITY ON-SITE LESS TIME / MORE TIME ◀——▶			
	1	2	3	4
1. Prefabricated Steel Truss	ⓧ			
2. Standard Steel Construction		ⓧ		
3. Cast-In-Place, Concrete		ⓧ		
4. Cast-In-Place, Concrete, Pre-Tensioned			ⓧ	
5. Precast Concrete	ⓧ			
6. Composite Steel and Concrete			ⓧ	
7. Concrete or Steel Arches, etc.				ⓧ

TABLE 14

COMPARATIVE TIME TO ERECT FACILITIES
ON-SITE VERSUS CONSTRUCTION TECHNIQUE

of services and construction technology. Construction time is also dependent upon the size of the project in terms of construction dollars, and the size of the contractor performing the construction, both of which vary from project to project. Therefore, no more specific guideline construction timetable can be provided.

3.3.6 The Unadjusted Facility Construction Cost

The unadjusted facility construction cost is the base cost of construction (Section 3.2) plus the costs of site contingencies. If comparison is being made of alternative facilities on the basis of capital investment using cost data relative to a special locale and uniform with regards to time, then the unadjusted construction costs will suffice. In subsequent sections the unadjusted construction cost, as indicated in Figure 20, will be called the Facility Construction Cost, or simply Construction Cost.

$$C = \text{THE UNADJUSTED FACILITY CONSTRUCTION COST} \\ \text{(OR "CONSTRUCTION COST")}$$

$$= \left(\begin{array}{c} \text{THE BASE COST} \\ \text{OF FACILITY} \\ \text{CONSTRUCTION} \\ \text{See Section 3.2} \end{array} \right) + \left(\begin{array}{c} \text{THE SPECIFIC COSTS OF} \\ \text{SITE CONTINGENCIES} \\ \text{See Sections 3.3.1} \\ \text{through 3.3.5} \end{array} \right)$$

FIGURE 20

DEFINITION OF FACILITY CONSTRUCTION COST

3.3.7 Comparative Cost Analyses of Specific Facilities

Several simple comparative analyses of selected facilities are presented below. Comparison is based strictly on cost elements as defined; this is a valid means to evaluate alternatives if an assumption is made that the alternatives are all equally effective. In most cases, utilization notwithstanding, they are equally effective. No attempt has been made to introduce detailed locational contingencies, although note is made of their possible impact where applicable.

Highway Crossings

For cost estimating purposes, an eighty-foot crossing for an at-grade highway, including lighting and drainage, where applicable, is assumed. Various options and their respective unadjusted construction costs are shown in Table 15. Based on the results in Table 15, it would appear that the minimum costs are associated with the conventional cast-in-place concrete overpasses. However, it is possible that traffic flows may be impeded during construction; related cost would have to be taken into consideration. With regards to the comparison between overpasses and underpasses, the cost decision clearly favors overpasses, except in the case of a cut and fill facility built in conjunction with new highway construction.

OPTION NUMBER	FACILITY TYPE	MATERIAL AND CONSTRUCTION METHODS	NUMBER OF			TERMINAL CONNECTORS	UNADJUSTED CONSTRUCTION COST
			SPANS	PIERS	MEDIANS		
1	Overpass	Conventional Steelwork	1-80'	2	0	Stairs	$ 57,994
2	"	"	"	2	0	Ramps	65,094
3	"	"	2-40'	4	1	Stairs	61,410
4	"	"	"	4	1	Ramps	68,410
5	Overpass	Conventional Cast-In-Place Concrete	1-80'	2	0	Stairs	47,194
6	"	"	"	2	0	Ramps	54,294
7	"	"	2-40'	4	1	Stairs	50,830
8	"	"	"	4	1	Ramps	57,930
9	Overpass	Precast Concrete	1-80'	2	0	Stairs	48,554
10	"	"	"	2	0	Ramps	55,654
11	"	"	2-40'	4	1	Stairs	53,310
12	"	"	"	4	1	Ramps	60,410
13	Underpass	Cut and Fill; New Road					62,240
14	"	Cut and Fill; Existing Road					93,200
15	"	Tunnelling; Existing Road					163,200

TABLE 15

HIGHWAY CROSSINGS COST COMPARISON

Street Crossings (CBD)

The grade-separated facilities assumed for a cost estimating example cross an existing urban, CBD street. The systems are 12 feet wide, enclosed, with an eighty-foot span. The cost of penetrating existing buildings is not included. The results are shown in Table 16. As the results indicate, the elevated walkway system built using conventional construction methods appears to be the most economic solution. The cut-and-cover underpass would incur substantial additional site specific costs, as would the tunnel. This comparison gives some insight into the cost of aesthetics as well, since the lower cost walkway systems also are probably the least aesthetically pleasing.

OPTION NUMBER	FACILITY TYPE	MATERIAL/ CONSTRUCTION METHODS	ADJUSTED CONSTRUCTION COST
1	Elevated Skyway	Conventional Steel, Enclosed, Heated and Air Conditioned	$ 87,200
2	Elevated Skyway	Conventional Concrete, Enclosed, Heated and A.C.	$ 76,320
3	Elevated Skyway	Steel Truss, Enclosed, Heated and Air Conditioned	$162,240
4	Underpass	Cut-and-Cover, Existing Street	$ 93,200
5	Underpass	Tunnel, Cast-In-Place, Concrete	$163,200

TABLE 16

COMPARISON OF VARIOUS STREET CROSSINGS COSTS

3.4 GEOGRAPHICAL AND TEMPORAL ADJUSTMENTS

When compiling facility cost data for comparison or as preliminary estimates, it may be necessary to make certain adjustments to cost elements in order to account for geographical or temporal differences. When the unadjusted construction cost computed in Section 3.3.6 is adjusted for geographical and/or temporal differences, it will be referred to as the adjusted construction cost.

3.4.1 Geographical Differences

Construction costs vary from region to region throughout the United States due to material supply characteristics, available labor and available construction technology. Therefore, in order to compare the cost of two similar types of facilities that are located in different regions, an adjustment factor must be applied to make the costs compatible. Likewise, in utilizing construction costs from one region to estimate costs in another, an adjustment is necessary.

The Dodge Manual for Building, Construction Pricing and Scheduling No. 8, 1973 (3) contains a locality adjustment index for 82 cities (representative of major regions) throughout the United States for 50 trade and subtrade categories with individual adjustments for materials, labor and total costs. These factors indicate local variations by taking into account local material and equipment prices, labor wage scales and transportation costs. Unit adjustment factors shown in the Dodge Manual range from 1.18 to 0.93 relative to a base cost.

Use of the Dodge locality adjustment factors is illustrated in Figure 21.

3.4.2 Temporal Differences

Inflation causes the price of commodities, including construction material and labor costs for pedestrian facilities to rise over time. In an economic analysis comparing capital investment, for proposed alternatives, it is preferred practice to omit any consideration of inflationary effects. However, when comparing specific costs previously incurred at different points in time, it is useful to apply known inflation factors to get comparable costs.

A tabulation of building cost indices (4) using December 1959 as a base of 100 is given in Table 17; forecasted inflation trends are given purely as a guide and should not be used in economic analyses

$$\frac{C_A}{F_A} = \frac{C_B}{F_B} = \text{BASE COST}$$

WHERE:

C_A = Value of Cost Element in Location A

C_B = Value of Cost Element in Location B

F_A = Locality (Dodge) Adjustment Factor for Location A

F_B = Locality (Dodge) Adjustment Factor for Location B

---

(1) To Find an Adjusted Cost in Location A Using a Cost Value Obtained for Location B, Compute:

$$C_A = \frac{F_A}{F_B} C_B$$

(2) To Adjust Estimates Obtained Using the Cost Factors Provided in Sections 3.2 and 3.3 (Base and Specific Costs) for Location A, Compute:

$$C_A = F_A \times \text{(Base and/or Specific Costs)}$$

FIGURE 21

USE OF THE DODGE LOCALITY CONSTRUCTION COST ADJUSTMENT FACTORS

(1) HISTORIC INFLATION TRENDS OF BUILDING COSTS DEC 1959 - MAY 1973
IN SIX MAJOR U.S. CITIES

	BALTIMORE	CHICAGO	DALLAS	LOS ANGELES	NEW YORK	SEATTLE	20 CITY USA AVERAGE
DEC 1959 (Base)	100	100	100	100	100	100	100
DEC 1960	100	101	107	103	100	101	102
DEC 1961	100	103	109	105	104	104	103
DEC 1962	100	105	111	108	106	108	106
DEC 1963	103	112	115	111	109	111	109
DEC 1964	105	114	116	114	112	114	112
DEC 1965	107	119	120	114	117	119	115
DEC 1966	114	124	126	119	119	123	118
DEC 1967	117	131	128	125	125	129	124
DEC 1968	128	140	141	138	138	143	137
DEC 1969	137	150	149	141	144	151	145
DEC 1970	149	160	156	153	154	161	157
DEC 1971	182	183	177	180	188	180	182
DEC 1972	192	196	198	206	200	192	197
MAY 1973	207	218	209	210	206	209	206

(2) FORECASTED INFLATION TRENDS OF BUILDING COSTS
MAY 1973 - DEC 1978

	USA AVERAGE
MAY 1973 (Base)	100
DEC 1973	105
DEC 1974	114
DEC 1975	125
DEC 1976	136
DEC 1977	148
DEC 1978	162

TABLE 17

HISTORIC AND FORECASTED INFLATION TRENDS

Source: ENR Building Cost Index History, 1913-1973
(Using a Base Change to December 1959
Equals 100)

due to their inherent uncertainty. The use of the inflation factors is given in Figure 22.

To Find The Cost in Year X, When the Cost in Year Y is Known, Compute:

$$C_X = \text{COST IN YEAR X}$$

$$= \frac{(\text{Factor for Year X})}{(\text{Factor for Year Y})} \quad (\text{Cost in Year Y})$$

Since most adjustments will be to convert a cost figure from a prior year (Y) to the May, 1973 price level, the above equation will have the special form:

$$C_{\text{Present}} = \frac{(\text{Factor for 1973})}{(\text{Factor for Year Y})} \quad (\text{Cost in Year Y})$$

FIGURE 22

USE OF THE ENR BUILDING COST INFLATION FACTORS

3.5 OPERATION AND MAINTENANCE COSTS

Most pedestrian facilities require some expenditures related to operation and maintenance (O&M). The importance of these costs varies considerably. The level of O&M cost is principally a function of:

- The facility's physical design properties;
- User group characteristics (e.g., shoppers, commuters);
- The degree of direct accessibility by maintenance crews;
- The proximity of the facility to other publicly maintained areas (whether the facility can be maintained as part of a larger maintenance area;

- The ownership of the facility (public or private); and

- Degree of enclosure of the system.

Furthermore, operating costs are dependent on additional factors such as:

- Level of comfort provided,
- Type of security required, and
- Availability of service.

Facilities such as pedestrian highway overpasses incur minimal O&M costs, primarily lighting and some annual maintenance. Large-scale systems, on the other hand, may incur substantial costs; where figures are available, they range from $150/square foot/year for enclosed pedestrian skyways to $2.25/square foot/year for open street malls.

A percentage breakdown of O&M costs based on walkway systems in several major urban centers is given in Table 18.

O & M CATEGORY	PERCENTAGE ALLOCATION
Taxes	25
Maintenance	26
Repairs	15
Utilities	14
Security	14
Miscellaneous	6
	100%

TABLE 18

PERCENTAGE ALLOCATION OF O & M COSTS - CBD SYSTEMS

Source: RTKL Associates, Inc. estimates.

The maintenance cost curve begins to rise sharply with the age of the structure especially during the last quarter of its projected life span, until such a time as repair costs cannot be justified. This is mainly attributed not to the structure of the facility, but to the deterioration of the mechanical systems operating within the facility. Most public facilities (such as walkways, overpasses, etc.), however, do not contain major mechanical systems, and therefore do not represent an accelerated maintenance cost curve. Maintenance costs remain relatively constant; increases reflect only the rising cost of labor and materials attributed to normal inflation. Therefore, maintenance cost curves will not be examined for these types of facilities.

3.6 THE FACILITY ECONOMIC INVESTMENT COST

In the preceding sections, the primary focus has been on the construction cost which can be expressed in current dollars. Although the cost of constructing large-scale pedestrian systems may involve capital investment over several years, very few problems are encountered in comparing the investment cost requirements of alternatives if only the costs of construction are considered. Unlike the costs of construction, however, the cost streams of expenditures for system operation and maintenance occur over the future years in which the facility is in service. Money has a time-dependent value that makes an amount now on-hand worth more than the promise of an equivalent amount at some future time. Hence, in terms of their "present value", future expenditures are of lower value than more current expenditures.

There are situations where the tradeoff between a low capital investment for construction combined with a high annual operating and maintenance expense may be directly competitive on the basis of present value to another alternative having a higher construction cost and lower annual upkeep. The more interesting comparison, however, is between the total economic cost of the facility and the total economic benefit derived from it. Given that a monetary value can be assigned to the benefit stream, the problem remains to express compatibly costs and benefits occurring at different times and in different time-phased patterns. Several methods for accomplishing this will be examined in this section.

Two equivalent methods for examining and comparing investment costs and annual expenses and/or benefits for different alternatives are:

- Present value of costs (benefits) method, and
- Equivalent uniform annual cost (benefit) method.

3.6.1 The Present Value Method

In the present value method, all costs both present and future are represented as a single sum which expresses the amount of capital required now (or at the start of the project) to finance facility construction and subsequent annual operating and maintenance expenses. This is accomplished by computing the present value of the O&M cost stream and adding it to the construction cost (assumed to be at its present value). The required computation is shown in Figure 23.

(PVC) = PRESENT VALUE OF FACILITY COSTS

$$= \begin{pmatrix}\text{ADJUSTED FACILITY}\\ \text{CONSTRUCTION COST}\end{pmatrix} + \begin{pmatrix}\text{PRESENT VALUE}\\ \text{OF O\&M COSTS}\end{pmatrix}$$

$$= \begin{pmatrix}\text{ADJUSTED FACILITY}\\ \text{CONSTRUCTION COST}\end{pmatrix} + \left[(\text{PVF}) \times \begin{pmatrix}\text{ANNUAL UNIFORM}\\ \text{O\&M COSTS}\end{pmatrix}\right]$$

Where: (PVF) = PRESENT VALUE FACTOR

$$= \frac{(1 + i)^N - 1}{i(1 + i)^N}$$

And:

N = The Facility Service Life (in Years)
i = Discount Factor (Interest Rate)

FIGURE 23

COMPUTATION OF THE PRESENT VALUE OF FACILITY COSTS

The present value computation in Figure 23 is expressed in its simplist form and assumes that the facility has zero salvage value at the end of its service life, and that annual O&M costs are uniform over the entire service life of the facility. The present value factors (PVF) have been tabulated for a wide range of i and N values, and are readily available.

In a similar manner, given that annual benefits are expressed in dollars, the present value of the benefit stream can be computed by summing over all years of service as shown in Figure 24.

(PVB) = PRESENT VALUE OF ANNUAL FACILITY BENEFITS

$$= \text{(PVF)} \times \left(\begin{array}{c}\text{ANNUAL UNIFORM}\\ \text{VALUE OF BENEFITS}\end{array}\right)$$

Where (PVF) is as defined in Figure 23.

FIGURE 24

COMPUTATION OF THE PRESENT VALUE OF FACILITY BENEFITS

The present values of cost and benefit can then be compared in one of several ways. Figure 25 shows the computations for the benefit to cost ratio method and the net present value method. When comparing alternatives, all other considerations being equal, the alternative with the greatest benefit to cost ratio or net present value is preferred. Only alternatives for which benefits exceed costs would be considered economically feasible.

3.6.2 The Equivalent Uniform Annual Cost Method

This method will yield results which are identical to those obtained using the present value method. In this case, the methods combine the cost of facility construction and the annual O&M expenses into an annual sum which represents a uniform value required in each year to repay the facility construction loan with interest, plus operate and maintain the facility. Note that the loan repayment is a conceptual representation and is not necessarily related to the

(B/C) = BENEFIT TO COST RATIO

= (PVB)/(PVC)

Or (NPV) = NET PRESENT VALUE OF BENEFITS OVER COSTS

= [(PVB) - (PVC)]

Where: (PVC) is as computed in Figure 23, and

(PVB) is as computed in Figure 24.

FIGURE 25

COMPUTATION OF BENEFIT/COST RATIOS AND NET PRESENT VALUES OF ALTERNATIVES

actual or proposed financing scheme. The equivalent uniform annual cost method is often preferred by highway planners and several examples of its application are given in Chapter 7. The basic computation is shown in Figure 26.

The benefit to cost ratio and net present value computed as shown in Figure 27 will yield the same result as that obtained using present value measures in Figure 25.

3.6.3 Sensitivity of Factors

In the computations described above, the interest rate and service life are usually chosen by judgment. Since the analysis is sensitive to these factors, it is often advantageous to determine their impact on solutions. This can be done by making a series of solutions for different i and different N.

The interest rate is probably the most critical factor since a change of several percent in the interest rate can change the results

$$(\text{AC}) = \text{EQUIVALENT UNIFORM ANNUAL FACILITY COST}$$

$$= \left(\begin{array}{c}\text{EQUIVALENT UNIFORM}\\ \text{ANNUAL COST OF}\\ \text{FACILITY CONSTRUCTION}\end{array}\right) + \left(\begin{array}{c}\text{ANNUAL UNIFORM}\\ \text{O\&M COSTS}\end{array}\right)$$

$$= \left[(\text{CRF})\left(\begin{array}{c}\text{ADJUSTED FACILITY}\\ \text{CONSTRUCTION COST}\end{array}\right)\right] + \left(\begin{array}{c}\text{ANNUAL UNIFORM}\\ \text{O\&M COSTS}\end{array}\right)$$

Where: $(\text{CRF}) = \text{CAPITAL RECOVERY FACTOR}$

$$= \frac{i(1+i)^N}{(1+i)^N - 1}$$

FIGURE 26

COMPUTATION OF THE EQUIVALENT ANNUAL FACILITY COST

$$(\text{B/C}) = \text{BENEFIT TO COST RATIO}$$

$$= \left(\begin{array}{c}\text{EQUIVALENT UNIFORM}\\ \text{ANNUAL FACILITY COST}\end{array}\right) \Big/ \left(\begin{array}{c}\text{ANNUAL VALUE OF}\\ \text{FACILITY BENEFITS}\end{array}\right)$$

$$= (\text{AC})/(\text{AB})$$

Or $(\text{NPV}) = $ NET PRESENT VALUE OF BENEFITS OVER COSTS

$$= [(\text{AB}) - (\text{AC})]\ (\text{PVF})$$

Where: PVF = The Present Value Factor Defined in Figure 23.

FIGURE 27

ALTERNATIVE COMPUTATION OF BENEFIT/COST RATIOS AND NET PRESENT VALUE OF ALTERNATIVES of the comparative analysis. Values between 5 and 10 percent are often used.* The impact is most significant when alternatives being compared have significantly different initial investment or annual O&M costs.

An analysis tends to be most sensitive to values of N, on the other hand, at the low range. This usually is not important for pedestrian facilities, which are apt to have a long potential service life. In general, the service life should be specified at the low end of its possible range for added conservatism, even though the analysis will be slightly more sensitive to service life at this value.

Service life, especially for extensive CBD systems, will often be difficult to estimate to any reasonable degree of accuracy. The consideration of longevity in this instance relates closely to the amortization period, interest rates, depreciation curves and equity and tax considerations. The developer/owner is usually concerned about realizing a financial return on his investment. Many public facilities, however, are implemented within different financial frameworks where the object is not one of realizing a financial return. Most often they have an initial one-time cost (for construction, etc.) which is not related to any considerations that could be utilized in determining the economic life of the facility. A possible method for determining the useful life of these facilities might lie in an examination of the physical and economic characteristics of the properties abutting the facility, that is, to examine the probability of significant change and redevelopment occurring in those areas that abut and directly affect the facility in terms of age, depreciation and revenue. This would require the difficult task of examining in detail abutting property conditions prior to determining a life cycle of each respective facility.

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* The current rate specified by the Federal Office of Management and Budget is 10%.

CHAPTER 3 REFERENCES

(1) On Foot Downtown, Joint Report by the Tronoto Planning Department (copy from Chapter 9 - Toronto).

(2) Interview with V. Ponte, October 31, 1973.

(3) Dodge Manual for Building, Construction, Pricing and Scheduling, 1973, No. 8; Dodge Building Cost Service - McGraw Hill Information Systems.

(4) ENR Building Code Index History 1913 to 1973.

CHAPTER 4. PEDESTRIAN TRIP ATTRACTION AND GENERATION

Pedestrian facilities are designed and implemented to be used, and the extent to which they are is dependent on two basic factors:

- Facility pathways must serve points of significant pedestrian trip generation or attraction; and
- Facility pathways must provide the pedestrian with benefits not found on alternative paths.

The first factor relates primarily to volume of pedestrian movement between two points and is covered in this chapter; the second factor addresses pedestrian pathway choice in terms of safety, convenience and comfort which is discussed in Chapter 5.

4.1 FACTORS INFLUENCING PEDESTRIAN TRIP EXCHANGE

The amount of pedestrian trip exchange between a given origin and destination depends on four elements:

- type of land use associated with the origin and destination centroids;
- number of trips generated by the origin toward all possible destinations;
- number of trips attracted by the destination from all possible origins; and
- the accessibility of the destination to the origin.

The type of land use associated with a given centroid determines to a large extent the type of pedestrian trips that will be generated and attracted. Department stores are associated with an entirely different subset of pedestrian trips than a high school, for example.

The number of trips attracted and generated by an activity is usually dependent on the size and scale of the centroid. Large retail stores attract and generate more trips than small retail stores; a large office building more than a smaller office building.

Accessibility of a destination to an origin is a key determinant in trip exchange. If a destination is too far to walk, or takes too long, or requires an inordinate amount of energy (such as climbing long flights of stairs), the trip may not be made at all, or an alternative mode of transportation may be used.

An understanding of these elements is especially important to the planning of facilities for successful utilization. For example, many grade-separated pedestrian systems involving retail activity depend on their ability to attract shoppers from at-grade competition. In order to be successful, these systems must first attract pedestrians by the type and size of the separated activity; the inducement to make a change in grade has to be strong. Also, the separated activity must be accessible—escalators may be needed to facilitate the level change and an adequate number of access points must be provided to avoid the necessity for pedestrians to make long walks or detours to gain access. Clearly, a few small shops that can be reached only by stairs are not likely to attract many trips.

4.2 TRIP PURPOSE

Trip purpose is closely related to the type of land use associated with centroids of pedestrian trip attraction and generation. Different land uses create different types of trips, and trip purpose is the essential concept that links centroids together.

Table 19 provides a framework for classifying pedestrian trips by purpose. The three basic types of trips as defined by Morris and Zisman(1) are:

- Terminal Trips - All trips made to and from home and nodes associated with transportation mode transfer such as bus stops, subway stations and parking lots.

- Functional Trips - Non-terminal trips made for the purpose of performing a specific function or functions unrelated to recreation or leisure activity; this category includes shopping trips, trips related to business and personal services, employee lunch trips and others such as deliveries.

I. TERMINAL TRIPS

II. FUNCTIONAL TRIPS

   A. BUSINESS
      1. Work
      2. Personal

   B. SHOPPING
      1. Primary
      2. Employee
      3. Incidental
      4. Lunch

   C. MISCELLANEOUS
      1. Deliveries
      2. Maintenance
      3. Others

III. RECREATIONAL TRIPS

   A. EXERCISE

   B. CULTURAL

   C. SOCIAL

   D. SIGHTSEEING

TABLE 19

TRIP PURPOSES

Source: Reference (1), Morris and Zisman, pp. 153-154.

- Recreational Trips - Trips related to recreation and pleasure including trips to theaters and sports events, social activities, and for the simple purpose of walking and strolling.

The category of functional trips comprises the majority of pedestrian trips and can be subdivided into business, shopping, and miscellaneous trips defined as follows:

- Business Trips(2) - Non-terminal trips made in conjunction with work or attainment of professional service that do not involve either an actual or potential purchase, such as trips between offices and banks, and trips to doctors and to lawyers;

- Shopping Trips(2) - Non-terminal trips made for the purpose of making a purchase of a product or personal service (dry-cleaners, barber), including eating and drinking; and

- Miscellaneous Trips - All other functional trips such as for deliveries and by patrolmen.

Within the general category of functional trips, the shopping trip subgroup requires additional definition as follows: (2)

- Primary - Shopping trips made by persons whose sole purpose is making a purchase;

- Employee - Shopping trips made by employees who shop before or after work, or on their lunch hour;

- Incidental - Shopping trips made by persons who have another primary trip purpose and incidentally shop; and

- Lunch - A special category of shopping trips made mostly by office workers and similar employees to restaurants and cafeterias during their lunch hour.

Within the context of the trip purpose framework shown in Table 19, an almost unlimited combination of trips is possible; for example, a business meeting may be combined with lunch, or a newspaper may be purchased on the way to the subway.(1)

Variations in pedestrian activity as a function of trip purpose have been examined by Maring(3) using data from a survey conducted in Washington, D. C. The survey subjects consisted of residents in two moderate-income apartment developments. Several of the results obtained from the survey are shown in Table 20.

As indicated in Table 20, the major percentage of walking trips for this residential population was for the purpose of shopping. It is interesting to note the dependence on walking for shopping purposes by persons aged 60 and over. On weekdays, walking trips to work were the second most frequent purpose. It was also determined from

TRIP PURPOSE	PERCENTAGE DISTRIBUTIONS									ALL TRIPS
	DAY OF WEEK				AGE GROUPS			SEX		
	Sat.	Sun.	Mon.	Tue.	18-39	40-59	60 and over	M	F	
TERMINAL (mode change)	1.2	2.0	12.0	13.2	1.1	15.5	0.0	12.0	7.5	7.3
WORK	2.3	0.0	18.1	23.5	12.4	9.2	4.3	17.4	6.8	11.5
SHOPPING	73.2	35.2	36.3	32.4	46.1	43.6	63.2	38.0	42.2	46.1
PERSONAL BUSINESS	3.5	0.0	7.2	7.4	5.6	9.9	4.3	2.2	7.5	4.9
RECREATION	11.6	29.4	12.0	10.3	20.2	12.0	13.0	15.2	16.5	14.6
SOCIAL	7.0	11.8	4.8	4.4	7.9	4.2	8.7	5.4	9.0	6.6
OTHER	1.2	21.6	9.6	8.8	6.7	10.6	6.5	9.8	10.5	9.0
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 20

PEDESTRIAN TRIP PURPOSE PERCENTAGE DISTRIBUTIONS

Source: Reference (3), Maring, pg. 19, Tables 5, 6, and 7.

the survey that the average number of walking trips per household during the four-day survey period was 3.3 trips; 21 percent of the households had no walking trips.(3)

Table 21 shows how pedestrian trip length varied by trip purpose in the Washington, D. C. residential study.

Pedestrian Trip Length (feet)	PERCENTAGE OF TRIPS LONGER THAN INDICATED LENGTH						
	Mode Change	Work	Shopping	Personal Business	Recreation	Social	Other
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1000	26.1	87.9	67.9	80.0	75.5	52.6	92.3
2000	0.0	87.9	13.9	40.0	34.1	15.8	80.8
3000	0.0	81.8	0.0	13.3	21.9	10.5	19.2
5280	0.0	63.6	0.0	13.3	14.6	10.5	7.7
8500	0.0	15.2	0.0	13.3	7.3	0.0	7.7
Estimated Mean Length (feet)	760	5890	1320	2760	2620	1640	3040

TABLE 21

TRIP LENGTH DISTRIBUTION BY TRIP PURPOSE
WASHINGTON, D.C. - RESIDENTIAL

Source: Reference (3), Maring, derived from Table 4.

Trip lengths such as those shown in Table 21 are often significantly affected by the location and distribution of trip destinations relative to the origin, especially for shopping and trips to work. Mode change trips to buses and taxis are very short, possibly a function of convenient bus stops and taxi stands. Interestingly, walking trips to work are the longest. By way of comparison, a similar study of pedestrian trip lengths, by purpose, was conducted for people entering and leaving several office buildings in midtown Manhattan. (4) Some comparative average walking distances are shown in Table 22.

Finally, trip purpose is an important factor in facility evaluation and design. Facilities succeed to the extent that they satisfy various needs for pedestrian convenience, comfort and safety. These elements are discussed in detail in the next chapter; however, the relative weight that is attached to each facility attribute changes

TRIP PURPOSE	AVERAGE PEDESTRIAN TRIP LENGTH (FEET) WASHINGTON, D.C. RESIDENTIAL AREA(3)	AVERAGE PEDESTRIAN TRIP LENGTH (FEET) MIDTOWN MANHATTAN BUSINESS DISTRICT(4)
TO WORK	5890	1880
SHOPPING	1320	2250
RECREATION/PLEASURE	2620	1670

TABLE 22

COMPARATIVE PEDESTRIAN TRIP LENGTHS
WASHINGTON, D.C. VERSUS MIDTOWN MANHATTAN

as a function of trip purpose. Clearly, directness of the pathway between two points is more important to the commuter than to the shopper. Table 23 shows the results of an informal survey taken among a group of urban planners associated with the design of pedestrian facilities.(5) The terms "high", "medium" and "low" are used to describe the relative importance of a given facility or pathway attribute to the purpose of the trip. Table 23 is intended to show the change in emphasis as the trip purpose changes.

Lessiev, from whom Table 24 was derived, has also noted the importance of weighing pedestrian system attributes to suit varying conditions associated with different trip types.

4.3 PEDESTRIAN TRIP CHARACTERISTICS

4.3.1 Related Research

The subject of pedestrian trip exchange, particularly as it relates to the four basic elements of land use, trip generation, trip attraction and accessibility (discussed in Section 4.1), and to trip purpose (discussed in Section 4.2) has received only scant attention. Several studies that have dealt with trip characteristics provide a great deal of useful information which is summarized in the following sections, but the need still exists for a continuing effort to understand the factors that influence pedestrian trip exchange and pathway

FACILITY ATTRIBUTE (see note)	TRIP PURPOSE				
	MODE CHANGE	(TRIPS TO) WORK	SHOPPING	BUSINESS	RECREATION
SAFETY	High	High	Medium	Medium	High
DIRECTNESS	High	High	Medium	High	Low
CONTINUITY	High	High	Medium	Medium	Low
CAPACITY	High	High	Medium	Medium	Low
ACCESSIBILITY	High	High	High	High	Medium
PROTECTION	High	Medium	High	High	Low
SECURITY	Medium	Medium	High	Medium	Medium
COHERENCE	High	Medium	Medium	Medium	Medium
INTEREST	Low	Low	Medium	Low	High
Note: Attributes are defined and described in Chapter 6					

TABLE 23

RELATIVE IMPORTANCE OF PEDESTRIAN FACILITY AND PATHWAY ATTRIBUTES BY TRIP PURPOSE

Source: Reference (5), RTKL Associates, Inc.

PEDESTRIAN TRIP ENVIRONMENT	APPLICABLE TRIP PURPOSES	IMPORTANT DESIGN CRITERIA
Residential Areas	Recreation To Work	Safety Convenience
Shopping and Entertainment Areas	Shopping Recreation	Safety Convenience Capacity Attractiveness
Employment Areas	Business To Work	Safety Speed Capacity

TABLE 24

WEIGHING OF PEDESTRIAN SYSTEM DESIGN CRITERIA

Source: Reference (10),Lessiev, pg. 338

choice. In particular, most prior studies have examined extensive areas comprising all, or a large part of, urban central business districts. As such, no specific pedestrian facilities are considered, nor is pathway choice treated at any useful level of detail. Nevertheless, these studies do provide valuable clues to an understanding of the pedestrian movement so important to the design and evaluation of facility utilization.

In contrast to research that simply addresses pedestrian volumes, rate of flow, walking distance or time, the studies cited in the following sections deal with the additional considerations of trip origin and destination, route and similar factors. Data collection was usually accomplished using some combination of on-site and office-based interviews or questionnaires, augmented where necessary by related pedestrian counts. In some cases, pedestrians were actually tracked along their individual trips, although this is extremely expensive with a low data yield. In most cases, the actual pedestrian trip data collection was preceded by a physical inventory of the study area so that origins, destinations, distances, elements of vertical change and so on were known and refined. Time-lapse and aerial (sky-count) photography has also been used.

In the following sections, selected results and conclusions characteristic of various types of pedestrian trips are discussed.

4.3.2 Terminal Trips

Most pedestrian trips are simply the beginning or the ending of more extensive journeys involving one or more other modes of transport such as automobile, bus, taxicab or train. These terminal links of the walking trip made in connection with other modes of transport will be called terminal trips.

In considering the four basic elements of pedestrian trip exchange, the trip generation and attraction capabilities of various mode-transfer terminals-- such as parking garages and bus stops-- are generally dependent on the type of terminal, its capacity and the dynamics of modal choice; these will not be considered here. Accessibility of the terminals, on the other hand, is a relevant subject for discussion. It has been shown that the degree to which pedestrian activity is attenuated with distance (or more generally, with pathway impedance) varies as a function of the mode of vehicular travel; that is, the length of a terminal trip will depend on the type and location of the vehicular mode.

In a study of pedestrian trips in midtown Manhattan, (4) it was found that approximately 75% of all walking trips involved another mode of transport. For trips to work, a breakdown as shown in Table 25 was developed. In Table 25, the distributions for subway, rail and commuter bus terminal trips are biased by the availability and geographic location of these modes; although they are not generally applicable, it is interesting to note the unusually long distances that employees are willing to walk to rail and commuter bus terminals. The relationship between local bus and auto trips shown in Table 25 is in general agreement with similar results obtained for journeys to work in Toronto CBD; the terminal trip walking time friction factors developed during the calibration of the Toronto pedestrian gravity model indicates that office workers are more indifferent to walking to parking garages than to bus or streetcar stops. (6) Table 25 also suggests that employees that drive and park on their journeys to work are willing, on the average, to walk greater distances than people who walk exclusively. It is suggested that this reflects, to some extent, the high cost of parking in the midtown Manhattan study area.

Walking trips to and from parking facilities form an important subject of all terminal trips. It has been shown that average walking distances to or from place of parking and destination will vary by urbanized area population and by trip purpose as shown in Table 26 and Figure 28.

Walking distances for people who park are further attenuated by the complex relationship between parking duration and cost (which also implies some value on pedestrian time). Table 27, a summary of average walking distance by parking duration and urbanized area population, shows, in general, that long-term parkers are willing to walk farther. A more detailed result which supports this notion is shown in Table 28 which relates an analysis conducted with the midtown Manhattan study cited above. Given that long-term parking is less expensive per unit of time than short-term parking, a gross relationship between cost and walking distance begins to develop. Winfrey, (9) citing a detailed study by Lisco, provides the useful finding that commuters in the Chicago Loop area are willing to pay about 12 cents per minute to reduce walking time from parking location to place of work. This 12 cents is composed of about 4 cents per minute for peak hour walking time and about 8 cents per minute related to the discomfort and inconvenience of walking.

Peterson has examined walking distances to bus stops in residential areas within Washington, D. C. (11) Data were collected

WALKING DISTANCE (feet)	PERCENTAGE OF TRIPS LONGER THAN INDICATED DISTANCE						
	TAXI	LOCAL BUS	SUBWAY	WALK ONLY	AUTO	RAIL	COMMUTER BUS
0	100	100	100	100	100	100	100
250	50	82	97	97	95	100	100
500	30	80	92	75	85	100	100
750	23	65	77	61	79	100	100
1000	21	38	50	53	74	77	100
1250	19	19	31	48	64	67	100
1500	17	10	20	45	49	64	100
1750	15	3	12	42	38	61	100
2000	14	2	11	39	34	60	100
3000	11	1	7	24	24	49	100
4000	9	0	5	17	22	10	95
5000	5		3	10	9	2	40
5280	4		2	8	6	0	26
6000	3		2	6	4		18
7000	2		1	2	2		8
8000	0		1	0	0		0
9000			1				
10000			0				
AVERAGE	892	926	1330	2001	2090	3231	4975
MEDIAN	160	890	1010	1100	1490	2970	4820

TABLE 25

CUMULATIVE PERCENTAGE DISTRIBUTIONS OF TERMINAL TRIPS WALKING DISTANCES IN MIDTOWN MANHATTAN BY MODE TRANSFER TYPE

Source: Adapted from Table 9 of Reference (4), Pushkarev and Zupan

URBANIZED AREA POPULATION	WALKING DISTANCES				
	SHOPPING	BUSINESS	WORK	OTHER	AVERAGE
10- 25,000	200	200	270	190	210
25- 50,000	280	240	400	210	280
50-100,000	350	290	410	260	330
100-250,000	470	390	500	340	420
250-500,000	570	450	670	380	530
500-1,000,000	560	590	650	500	630
1,000,000 and over	660	640	780	580	720

TABLE 26

AVERAGE WALKING DISTANCES (FEET) BY TRIP PURPOSE AND URBANIZED AREA POPULATION

Source: Reference (8), DOT/FHWA, Figure 16, pg. 33.

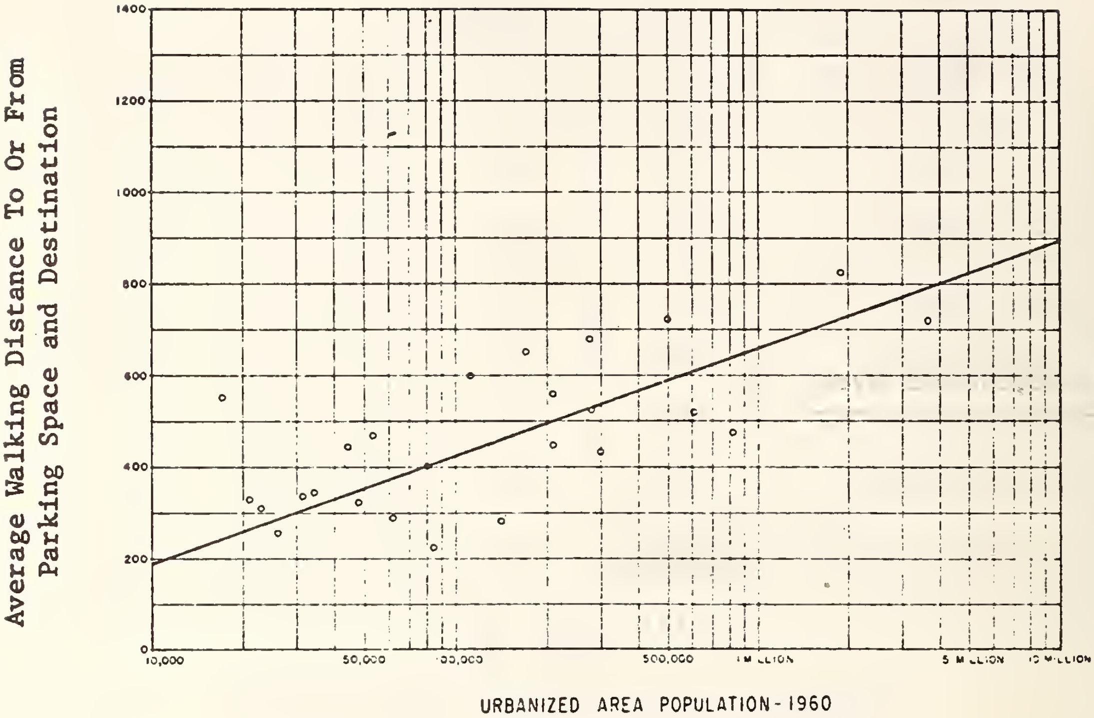

FIGURE 28

AVERAGE WALKING DISTANCE IN RELATION TO URBANIZED AREA POPULATION

SOURCE: Reference (7), Wilbur Smith and Associates, Figure 11, page 14.

URBANIZED AREA POPULATION	WALKING DISTANCE (FEET)							
	PARKING DURATION (HOURS)							
	0-1/4	1/4-1/2	1/2-1	1-2	2-3	3-4	4-5	5 and over
10- 25,000	170	200	220	240	260	290	290	330
25- 50,000	160	210	270	290	330	370	430	500
50-100,000	180	280	310	350	360	380	370	430
100-250,000	260	300	420	390	500	500	500	550
250-500,000	280	330	440	500	550	570	610	740
500-1,000,000	260	430	480	490	550	510	610	900
1,000,000 and over	330	430	520	560	620	660	700	800

TABLE 27

AVERAGE PARKING DISTANCE (FEET) BY PARKING DURATION AND URBANIZED AREA POPULATION

Source: Reference (8), DOT/FHWA, Table 17, pg. 34.

WALKING DISTANCE (FEET)	PERCENTAGE OF TRIPS LONGER THAN INDICATED DISTANCE	
	SHORT-TERM PARKING	LONG-TERM PARKING
0	100	100
250	81	91
500	54	84
750	51	77
1000	45	63
1250	35	53
1500	30	44
1750	25	39
2000	20	32
3000	12	18
4000	2	8
5000	1	3
5280	1	3
6000	0	1
7000		0
AVERAGE	1198	1780
MEDIAN	700	1220

TABLE 28

CUMULATIVE PERCENTAGE DISTRIBUTION OF WALKING DISTANCES FOR SHORT- VERSUS LONG-TERM PARKING

Source: Reference (4), adapted from Table 10.

from 4,085 questionnaires returned by riders on the citywide bus transit system. Results were compared on the basis of car ownership (yes or no) and a Socio-Economic Status (SES) index developed in another study for classifying residential neighborhoods on the basis of high, medium, medium-low and low. A primary result from this study is shown in Table 29.

CAR OWNERSHIP	SOCIO-ECONOMIC STATUS (SES)	MEAN DISTANCE (FEET) WALKED TO BUS STOP
Yes	High	614
	Medium	570
	Medium-Low	596
	Low	700
No	High	494
	Medium	596
	Medium-Low	634
	Low	727

TABLE 29

MEAN WALKING DISTANCES TO BUS STOPS RELATED TO CAR OWNERSHIP AND SOCIO-ECONOMIC STATUS

Statistical analysis of the study data indicated that where car ownership was involved, the walking distances were not significantly different by SES. Where no car ownership was involved, distances walked by riders in the medium and medium-low SES groups differed significantly from those in the high and low SES groups.

4.3.3 Business Trips

As defined in Section 4.2, business trips are non-terminal trips made in conjunction with work or attainment of professional service; they do not involve either an actual or potential purchase and are typified by pedestrian trips between offices and banks, trips to doctors and lawyers, and so on. This type of walking trip was studied in downtown Washington, D. C. and in midtown Manhattan. Major conclusions stated in each of these studies are presented in the following section.

Downtown Washington, D. C.

The following conclusions were developed by Morris (2) using counts and interviews taken at the entrances to two office buildings in downtown Washington, D. C.:

1. By rough approximation, each downtown employee generates two business trips (by all modes) per business day; trips are distributed according to employment densities.

2. A limited interview survey of business trips by all modes produced the trip length results shown in Table 30.

3. The distribution of business trips by mode of transport was as shown in Table 31.

Midtown Manhattan

The following results were presented by Pushkarev and Zupan(4) based on 1400 interviews representing a sample of about 17,000 pedestrians entering or leaving two major office buildings in midtown Manhattan:

1. For all pedestrian trips that were not home-based (to or from residences), trips for the purpose of eating were the most numerous, followed by business trips and then by shopping, pleasure, and delivery trips in that order.

2. Business trips were found to have the walking distance distribution shown in Table 32; note that the distribution for Washington, D. C. shown in Table 30 included all transport modes.

3. Approximately 50 to 55% of all business trips recorded were walk only trips.

4.3.4 Shopping Trips

As defined in Section 4.2, shopping trips are non-terminal trips made for the purpose of making a purchase of a product or personal service such as dry-cleaning or banking, and include trips for eating and drinking. Of all functional trip types, pedestrian shopping trips have received the most attention. In the sections

DISTANCE (feet)	TRIPS LONGER THAN THE INDICATED DISTANCE	
	PERCENTAGE	NUMBER
0	100	52
500	89	46
1000	77	40
1500	69	36
2000	54	28
2500	44	23
3000	40	21
3500	35	18
4000	35	18
4500	29	15
5000	8	4
MEAN TRIP LENGTH - 2800 FEET MEDIAN TRIP LENGTH - 2100 FEET		

TABLE 30

BUSINESS TRIP LENGTH DISTRIBUTION BY ALL TRANSPORT MODES FOR DOWNTOWN WASHINGTON, D.C.
(Based on 52 Employee Interviews)

Source: Reference (2), Morris, derived from Table 2, pg. 212

TRANSPORT MODE	PERCENTAGE	NUMBER
WALK ONLY	73	38
MASS TRANSIT	12	6
PRIVATE AUTO	10	5
TAXICABS	5	3
	100	52

TABLE 31

DISTRIBUTION OF BUSINESS TRIPS BY TRANSPORT MODE FOR DOWNTOWN WASHINGTON, D.C.
(Based on 52 Employee Interviews)

Source: Reference (2), Morris, page 213

that follow, some general results and conclusions are presented, and more detailed results are given for employee shopping and lunch trips.

General Results

The following results are due to Morris, (2) and Morris and Zisman (1) based on an extensive data collection effort in downtown Washington, D. C. including 1,314 pedestrian interviews, approximately 19,100 office-based employee questionnaires (66 percent returned of 29,000 distributed), and a manual all-day pedestrian count. The primary findings were:

1. The average number of stops per shopping trip and the composition of shopping trip subtypes is given in Table 33.
2. The average overall shopping trip covered approximately 2,000 feet; the average distance between stops in the Washington, D. C. study area was 1,250 feet.
3. The trip attraction of retail stores, expressed as thousands of customers per week, as a function of store size, expressed as the number of full-time employees, is given in Figure 29.

One particularly interesting result presented by Morris is shown in Figure 30. Using data related to the exchange of trips between stores, an analysis was made of the mutual attraction that exists between one store and another. The conclusion is that each retail store will attract a portion of its shoppers from other stores; that is, each store will attract secondary trips from the primary trips made to other stores. As shown in Figure 30, the secondary trip attraction is related to the size of the attractor and its distance from the generator.

As an example using Figure 30, Morris (2) notes that a store of 200,000 square feet will attract approximately 21 secondary shopping trips for each 100 trips generated by another store located at a distance of 1,000 feet. In a similar manner, three stores of 200,000 square feet each will attract a total of 63 shopping trips for each 100 trips generated by a 600,000 square feet store located 1,000 feet away; however, the larger store will attract only 35 trips of each 100 trips generated by the combination of three smaller stores. This example, as Morris suggests, points up the attraction benefits that accrue to clusters of small, diverse retail activities. The curves also illustrate

WALKING DISTANCE (FEET)	PERCENTAGE OF ALL BUSINESS TRIPS LONGER THAN THE INDICATED DISTANCE
0	100
500	86
1000	65
1500	46
2000	35
3000	18
4000	6
5000	2
MEAN WALKING TRIP LENGTH - 1737 FEET MEDIAN WALKING TRIP LENGTH - 1405 FEET	

TABLE 32

PERCENTAGE DISTRIBUTION OF BUSINESS WALKING TRIPS FOR MIDTOWN MANHATTAN

Source: Reference (4), Pushkarev and Zupan, Table 8.

SHOPPING TRIP SUBTYPE	AVERAGE NUMBER OF STOPS PER SHOPPING TRIP	PERCENTAGE OF ALL SHOPPING STOPS
PRIMARY	2.5	73
EMPLOYEE	1.5	12
INCIDENTAL	2.0	15
AVERAGE	2.2	--

TABLE 33

CHARACTERISTICS OF SHOPPING TRIP SUBTYPES BASED ON WASHINGTON, D.C. STUDY

Source: Reference (2), Morris, Table 3, pg. 214.

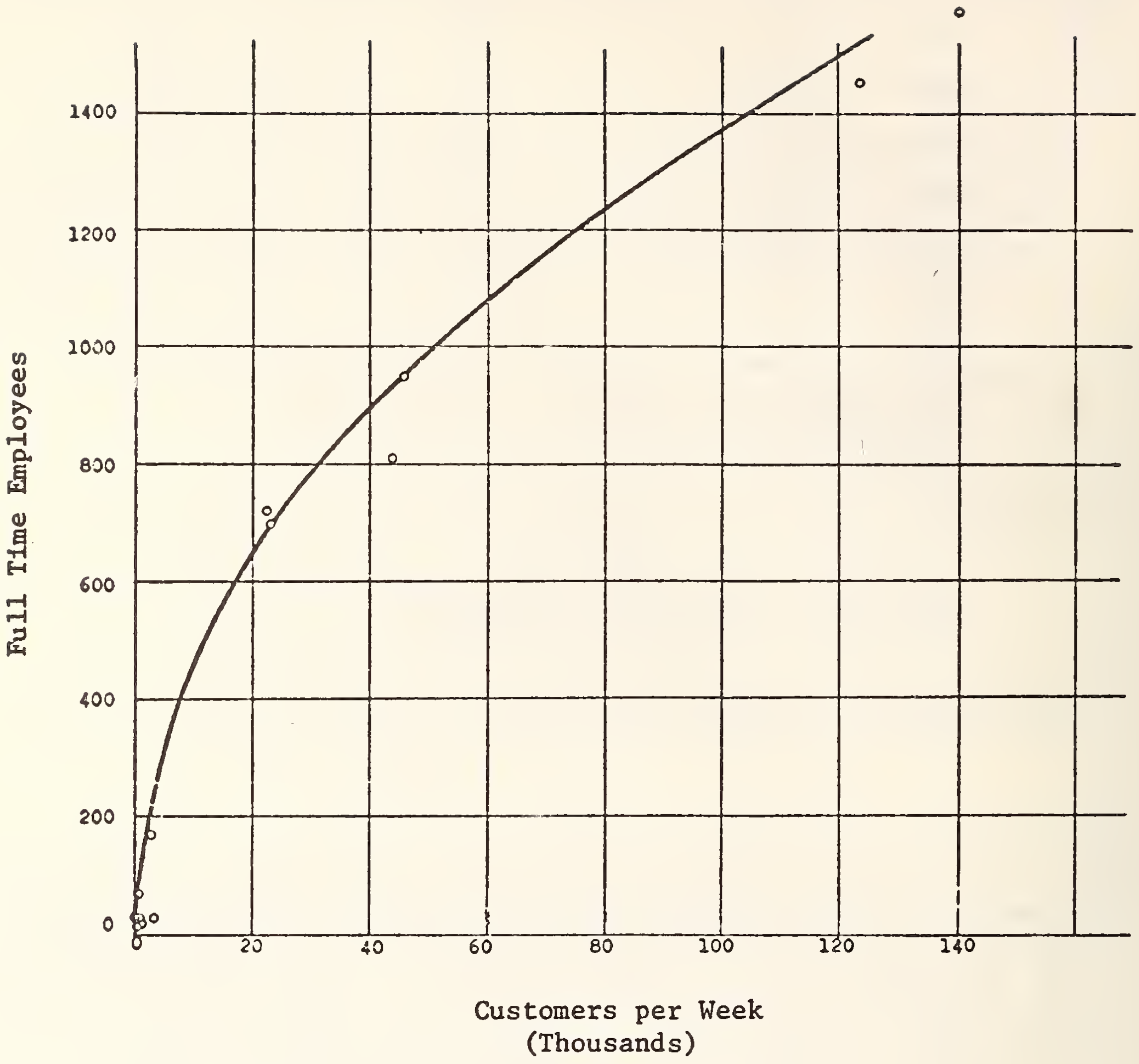

FIGURE 29

RETAIL STORE TRIP ATTRACTION AS A FUNCTION OF STORE SIZE

SOURCE: Reference (2), Morris, Figure 1, page 215.

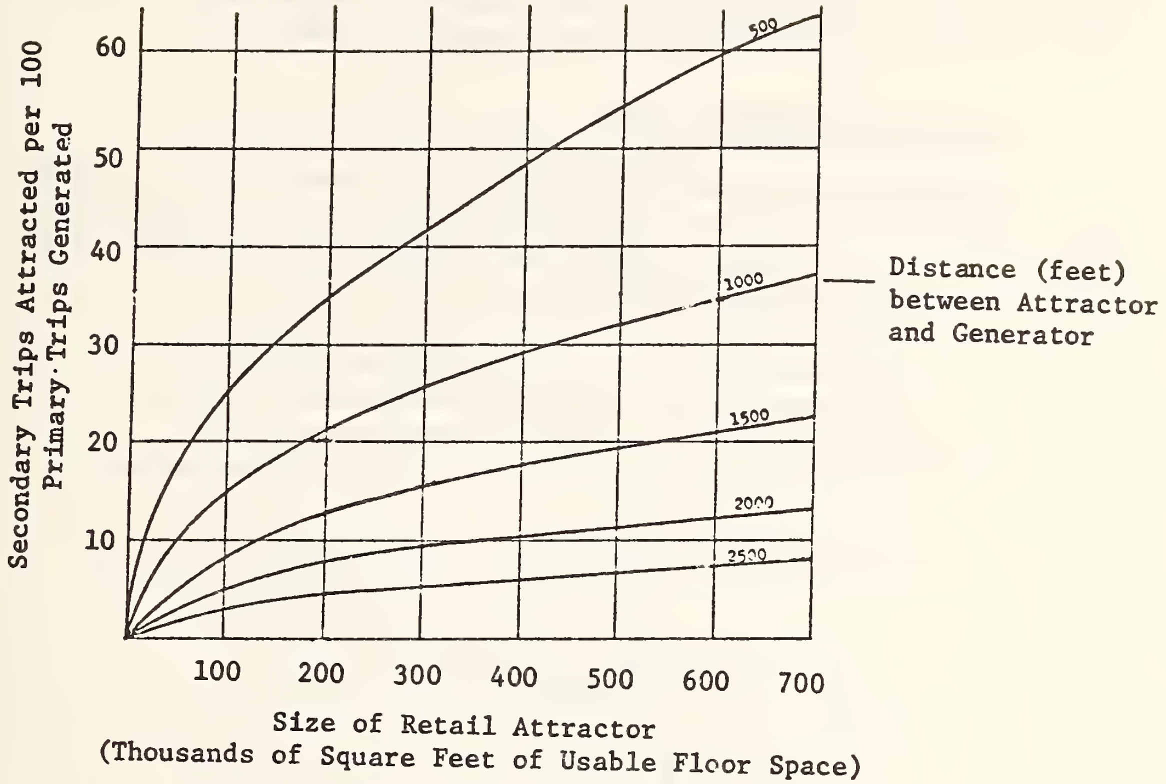

FIGURE 30

TRIP EXCHANGES BETWEEN RETAIL STORES

SOURCE: Reference (2), Morris, Figure 3b, page 218.

the advantageous increase in overall levels of shopping activity that come from having concentrated, rather than spread-out, retail shopping areas.

A word of caution is in order regarding Figure 30. The relationships were obtained from a limited number of data points and also reflect the geographical bias of the retail activity in the Washington, D. C. study area. Hence, the curves in Figure 30 should be viewed primarily for their conceptual value rather than as a source of absolute between-store exchange rates.

Employee Shopping Trips

Shopping trips made by downtown employees who shop during their lunch hour, or before or after work have been studied in Washington, D. C., in Toronto, Ontario and in midtown Manhattan. The major results obtained are as follows:

1. In Washington, D. C. Morris(2) analyzed the attraction of workers to shopping using a simple gravity model approach. A retail index was computed (see Figure 31) and related to responses

R_i = RETAIL INDEX FOR THE ith OFFICE EMPLOYEE CENTROID

$$= \sum_j E_j / D_{ij}^2$$

where: E_j = number of full-time employees for the jth retail store (attraction measure), and

D_{ij} = distance (feet) between the ith office centroid and the jth retail store (separation or accessibility measure)

FIGURE 31

COMPUTATION OF THE RETAIL INDEX FOR EMPLOYEE SHOPPING ATTRACTION IN WASHINGTON, D.C.

Source: Reference (2), Morris (see Table 4), pg. 217.

obtained from an office-employee-based questionnaire to obtain the results shown in Figure 32. Note that the attraction of employees to shopping (lunch trips are excluded) reaches an upper limit of about 30%. The retail index represents the cumulative effect on office employees of the six largest retail attractors in downtown Washington. An office building adjacent to the retail area has an index of about 30; those located one mile away have an index of about 2.

2. A curve similar to that shown in Figure 32 was developed for the Toronto central business district.(6) A measure called accessibility which is based on retail trip attraction and office-store separation was derived using the results of a lunch hour pedestrian circulation model developed for the Toronto CBD. This index was related, in a manner similar to that employed by Morris, using an office-based questionnaire response to obtain the results, shown in Figure 33. In Toronto, an upper limit on employee attraction was reached at about 80% in contrast to the 30% obtained in Washington, D. C. However, the Toronto study included employee lunch trips which were excluded in the Washington study.

3. In midtown Manhattan, Pushkarev and Zupan(4) found that approximately 72% of all employee shopping trips were walk only trips, and that walking trips had a length distribution as shown in Table 34. The mean walking distance shown here compares well with that obtained for all shopping trips in downtown Washington, D. C. [see Section 4.3.4.1(2)].

4. The Toronto study(6) produced a breakdown of employee lunch hour circulation as shown in Table 35. The number of stops per employee lunch trip is 1.70; excluding stops for restaurant,

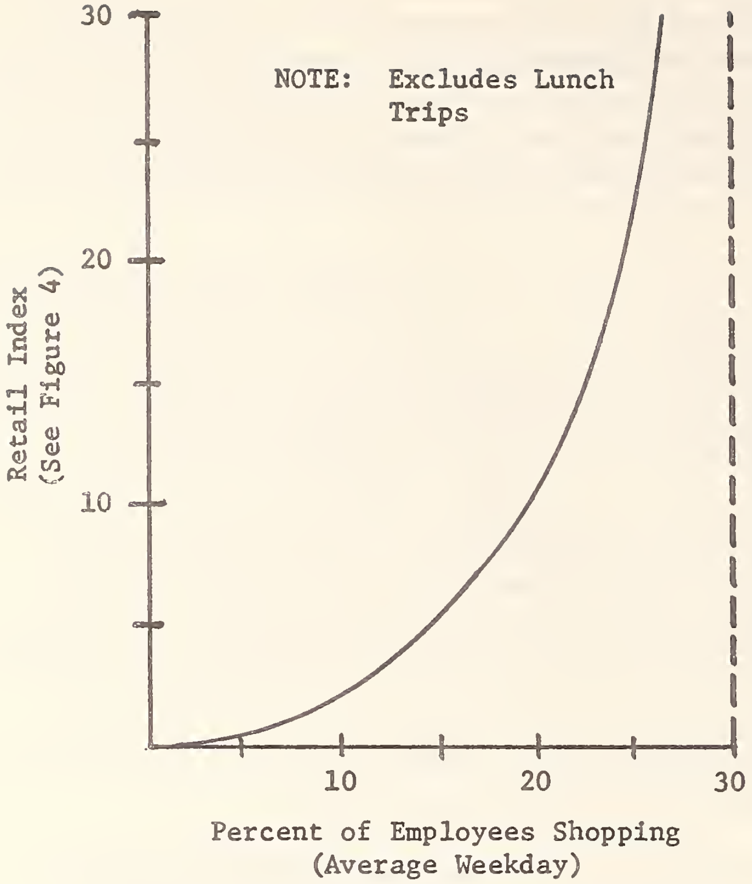

FIGURE 32

RETAIL ATTRACTION TO EMPLOYEES
(Washington, D.C.)

SOURCE: Reference (1), Morris and Zisman, Figure 1, page 155.

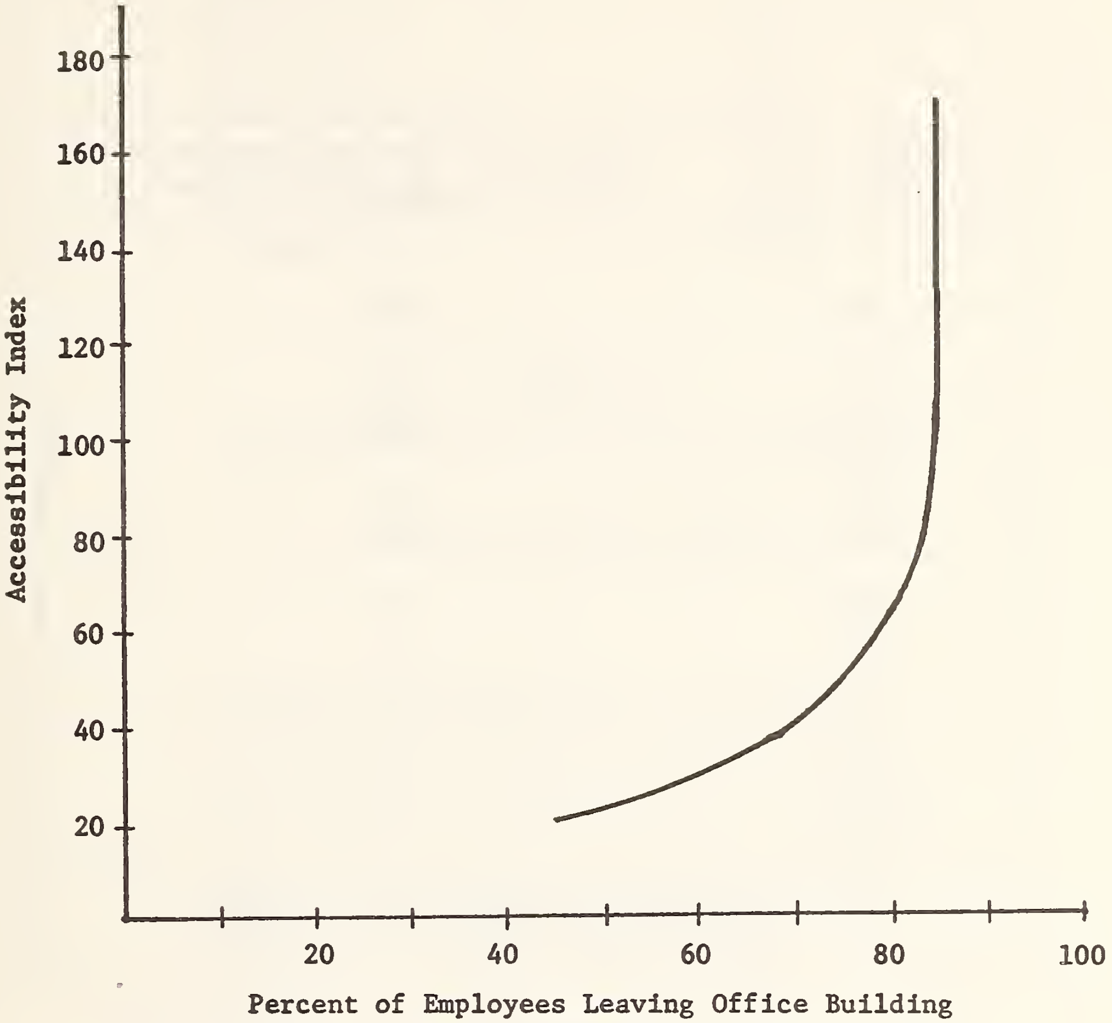

FIGURE 33

RETAIL ATTRACTION TO EMPLOYEES
(Toronto, Ontario)

SOURCE: Reference (6), Ness, Morrall, and Hutchinson, Figure 3, page 15.

WALKING DISTANCE (FEET)	PERCENTAGE OF EMPLOYEE SHOPPING TRIPS LONGER THAN INDICATED DISTANCE
0	100
500	88
1000	64
1500	43
2000	32
3000	22
4000	18
5000	11
6000	11
7000	11
8000	10
9000	8
10000	5

MEAN WALKING DISTANCE - 2253 FEET

MEDIAN WALKING DISTANCE - 1250 FEET

TABLE 34

DISTRIBUTION OF WALKING DISTANCE FOR EMPLOYEE SHOPPING TRIPS IN MIDTOWN MANHATTAN

Source: Reference (4), Pushkarev and Zupan, derived from Table 8, pg. 51.

TRIP ACTIVITY	STOPS PER PERSON
Department Store	0.57
Retail Shop	0.36
Restaurant	0.36
Personal Business	0.29
Recreation	0.11
Transportation	0.01
Average	1.70

TABLE 35

EMPLOYEE LUNCH HOUR TRIP ACTIVITY BREAKDOWN

Source: Reference (6), Ness, Morrall, and Hutchinson, Table 2, pg. 14.

recreation and transportation, this figure is 1.22 stops per employee shopper as compared to 1.5 stops per employee shopper determined in the Washington, D. C. study.(2)

5. The lunch hour trips in Toronto were broken down into stages with trip times as shown in Table 36.

Lunch Trips

Lunch trips are a special category of shopping trips made primarily by office workers and similar employees to restaurants and cafeterias during their lunch hour. This type of pedestrian trip was treated as a separate entity in both the Washington, D. C. and the Manhattan studies. Major results are as follows:

1. In downtown Washington, D. C., it was estimated that from 70 to 80% of downtown employees leave office buildings to go to lunch, the figure being as high as 85%. Where no cafeterias are available in buildings, average lunch trip length was 470 feet;(1) a distribution of lunch trip lengths is shown in Figure 34.

TRIP STAGE	TRIP LENGTH (MINUTES) MEAN	MEDIAN
Office to Shop	6.0	5.2
Shop to Shop	4.4	3.5
Shop to Office	6.9	6.3
Total Trip	17.3	15.0

TABLE 36

EMPLOYEE LUNCH HOUR TRIP BREAKDOWN - TORONTO CBD

2. In midtown Manhattan, eating trips made up about one-third of all trips that were not home-based; about 87% of all eating trips involved walking only; average trip length was 1073 feet, and the median length was 810 feet.

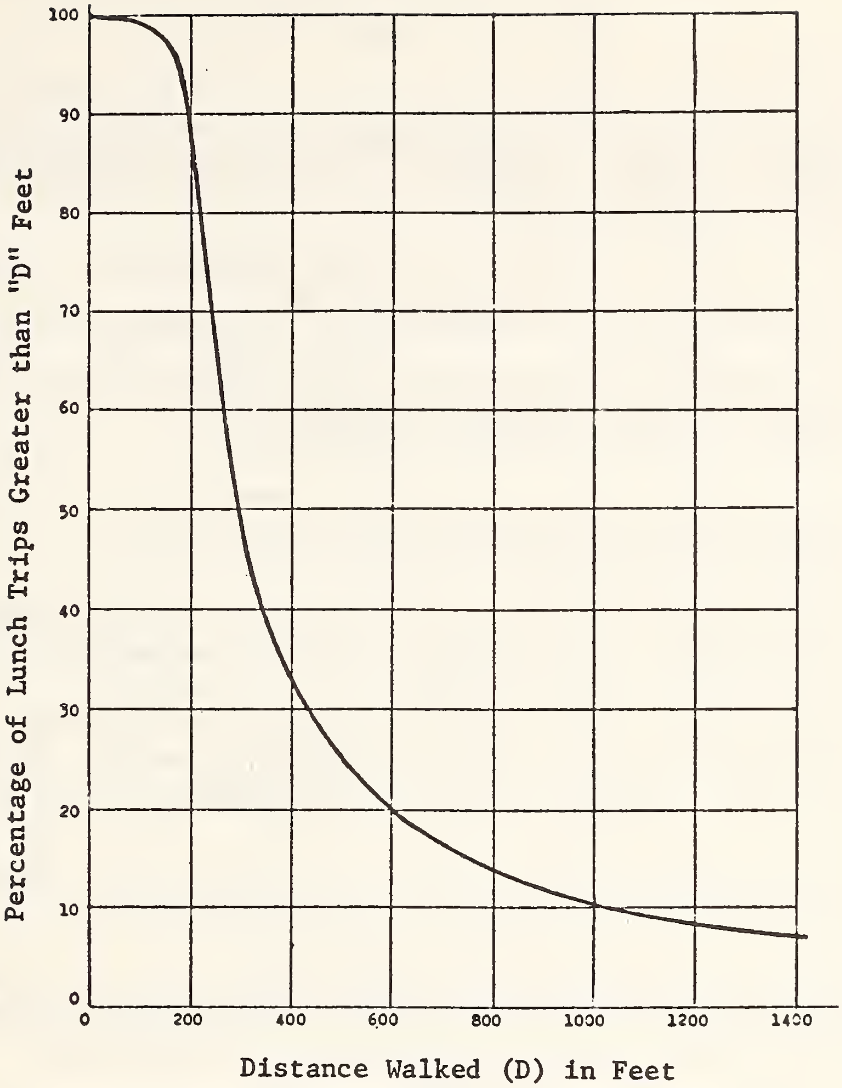

FIGURE 34

DISTRIBUTION OF WALKING TRIP LENGTHS FOR TYPICAL EMPLOYEE LUNCH TRIPS IN DOWNTOWN WASHINGTON, D.C.

SOURCE: Reference (2), Morris, Figure 4, page 219.

CHAPTER 4 REFERENCES

(1) R. L. Morris and S. B. Zisman, "The Pedestrian, Downtown and The Planner," *Journal of the American Institute of Planners*, vol. 28, August 1962.

(2) R. L. Morris, "Evaluating the Requirements for a Downtown Circulation System," *Highway Research Board Bulletin 347*, 1962.

(3) G. E. Maring, "Pedestrian Travel Characteristics," *Highway Research Record Number 406*, 1972.

(4) B. Pushkarev and J. M. Zupan, "Pedestrian Travel Demand," *Highway Research Record Number 355*, 1971.

(5) RTKL Associates, Inc., "The Importance of Pedestrian Facility Attributes by Trip Purpose," Unpublished Report, January 1971.

(6) M. P. Ness, J. F. Morrall, and B. G. Hutchinson, "An Analysis of Central Business District Pedestrian Circulation Patterns," *Highway Research Record Number 283*, 1969.

(7) Wilber Smith and Associates, *Parking in the City Center*, The Automobile Manufacturers Associate, May 1965.

(8) R. W. Stout, *A Report on CBD Parking*, Highway Planning Technical Report Number 23, U. S. Department of Transportation, Federal Highway Administration, April 1971.

(9) R. Winfrey, *Economic Analysis for Highways*, International Textbook Company, Chapter 11 on Road-User Consequences, 1969.

(10) E. J. Lessiev, "Pedestrian Circulation Systems," *Proceedings* of the 7th Annual Meeting of the Transportation Research Forum, 1966.

(11) S. G. Petersen, "Walking Distances to Bus Stops in Washington, D.C., Residential Areas," *Traffic Engineering*, December 1968.

CHAPTER 5. PEDESTRIAN-RELATED IMPACTS

Unless pedestrian systems are designed to improve pedestrian movement and benefit the walking tripmaker, none of the subsequent beneficial impacts on vehicular circulation, retail activity and other related elements will be realized. Facilities should be conceived, planned and implemented to overcome the impedances of walking as perceived by the pedestrian himself.

In a survey reported by Maring(24), respondents were asked to rank those factors that discourage them from walking. The results of this survey are shown in Table 37. The "others" category includes distance, time, laziness, lighting, health and heavy shopping bundles.

FACTOR RANK	FACTORS THAT DISCOURAGE WALKING (Number of Responses)					
	Unfavorable Weather	Crime	Lack of Adequate Sidewalk	Heavy Auto Traffic	Smog or Pollution	Others
1	26	37	0	3	0	16
2	24	17	1	6	4	6
3	5	2	6	11	7	2
4	3	3	4	4	6	2
5	1	2	7	2	6	0
6	0	2	3	2	1	0

TABLE 37

RANKING OF FACTORS THAT DISCOURAGE WALKING

Source: Reference (24), Maring, Table 8, pg. 19.

Interestingly, safety, as implied by the heavy auto traffic category, and convenience, implicit in the lack of adequate sidewalks, and the other categories do not rank high on the pedestrian list. A disregard by the pedestrian for his own safety has often been noted, but convenience has been shown to be an important factor in pedestrian choice even if the pedestrian is not cognizant of it. Of particular interest is the high importance accorded weather protection and security by virtue of the results in Table 37.

In the following sections, pedestrian safety, convenience, comfort and other impacts, along with appropriate sub-topics are discussed. The objective of this discussion is to provide insights into the pedestrian-related impacts, pedestrian system attributes and the relationships between them. The discussion is generally in accordance with the framework shown in Table 38.

PEDESTRIAN-RELATED IMPACTS (BENEFITS)	PEDESTRIAN SYSTEM PATHWAY ATTRIBUTES
Safety	Separation
Convenience	Directness Continuity Capacity Availability
Comfort and Others	Protection Security Coherence Interest

TABLE 38

PEDESTRIAN-RELATED IMPACTS AND ASSOCIATED PATHWAY ATTRIBUTES

5.1 SAFETY AND SEPARATION

Pedestrian safety is universally accepted as one of the primary benefits of pedestrian/vehicular separation; it is quoted as an objective, and usually as the primary objective, of separation in nearly all literature dealing with the subject. In the following sections, the magnitude of the pedestrian safety problem is considered, accident risk and the impact of separation on risk is examined, and several important pedestrian accident causal factors are discussed. Finally, a brief analysis of the cost of pedestrian accidents is presented.

5.1.1 Magnitude of the Pedestrian Safety Problem

There is little question that the conflict between people on foot and motor vehicles is a serious problem. The number of deaths resulting from this conflict (as shown in Figure 35) is again on the rise after reaching a minimum in the late fifties. In 1971 alone (as Figure 36 shows), 10,600 people lost their lives as a result of being struck by vehicles, and another 150,000 were injured, often seriously. One in every five motor vehicle-related deaths was a pedestrian.(1)

In urban areas, pedestrian deaths exceed all other motor vehicle-related types of accident, as shown in Table 39.

5.1.2 Accident Risk

Traditionally, the study of pedestrian accidents has centered on attempts to relate measures expressing the probability of being involved in an accident to one or more accident causal factors. The involvement probabilities are usually termed pedestrian risk. Estimates of risk, obtained using actual accident statistics together with some measure of exposure, take the following general form:

$$\text{Risk} = \frac{\text{Number of Pedestrian Accidents}}{\text{Extent of Pedestrian Exposure}}$$

The measurement of pedestrian exposure relative to actual accident involvement represents the primary problem in analysis of pedestrian risk. In an effort to reduce risk to parametric form, exposure measures such as the number of vehicle miles and population, have been used, neither of which represents a true measure of exposure. Ideally, risk should be expressed on the basis of a "per crossing", or a "per second of potential conflict" measure of exposure; however, the difficulties of obtaining this information for a rare event such as a pedestrian accident generally preclude measures of this type.

Notwithstanding the problems associated with measuring exposure, much research has been conducted on the relationship between relative risk and accident causal factors. Reference (2) provides for a compilation of the scope of these efforts. A list of the factors considered is shown in Table 40; several of the factors that are particularly relevant to the impact of separation are discussed in Section 5.1.4.

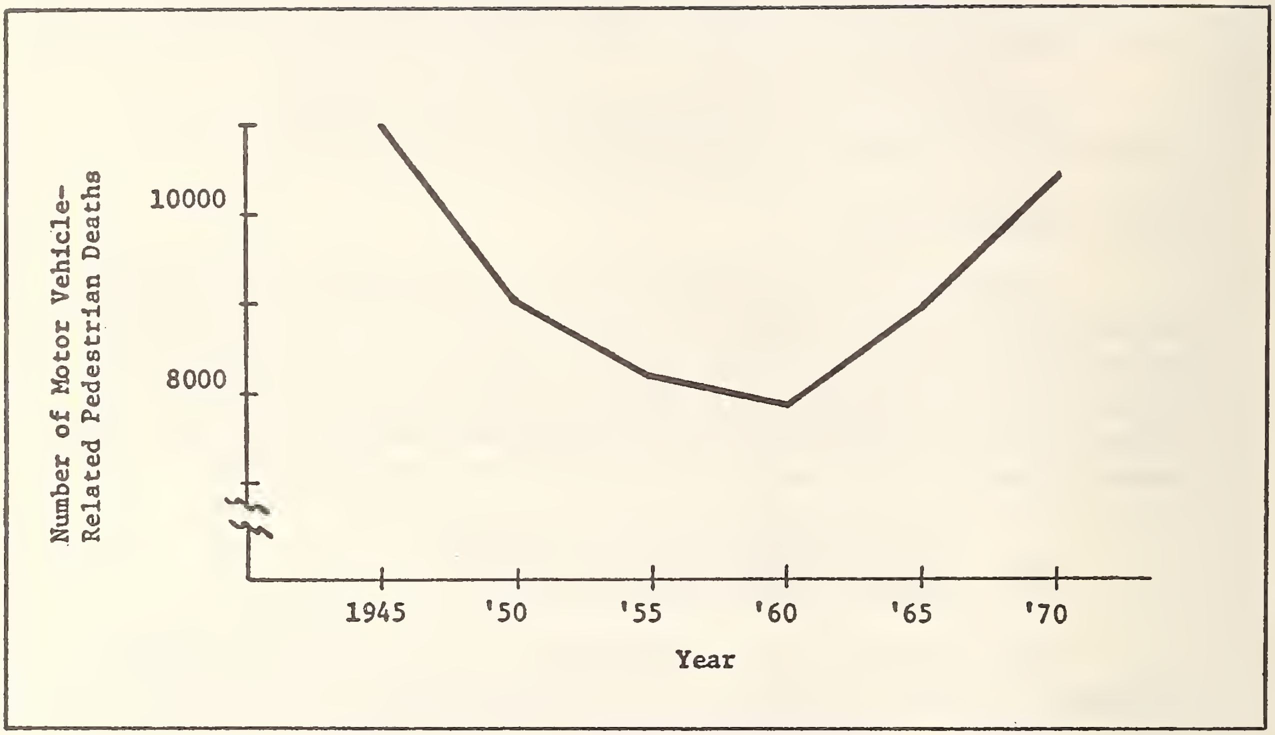

FIGURE 35

PEDESTRIAN DEATHS PER YEAR

Source: Reference (1), Accident Facts, page 58.

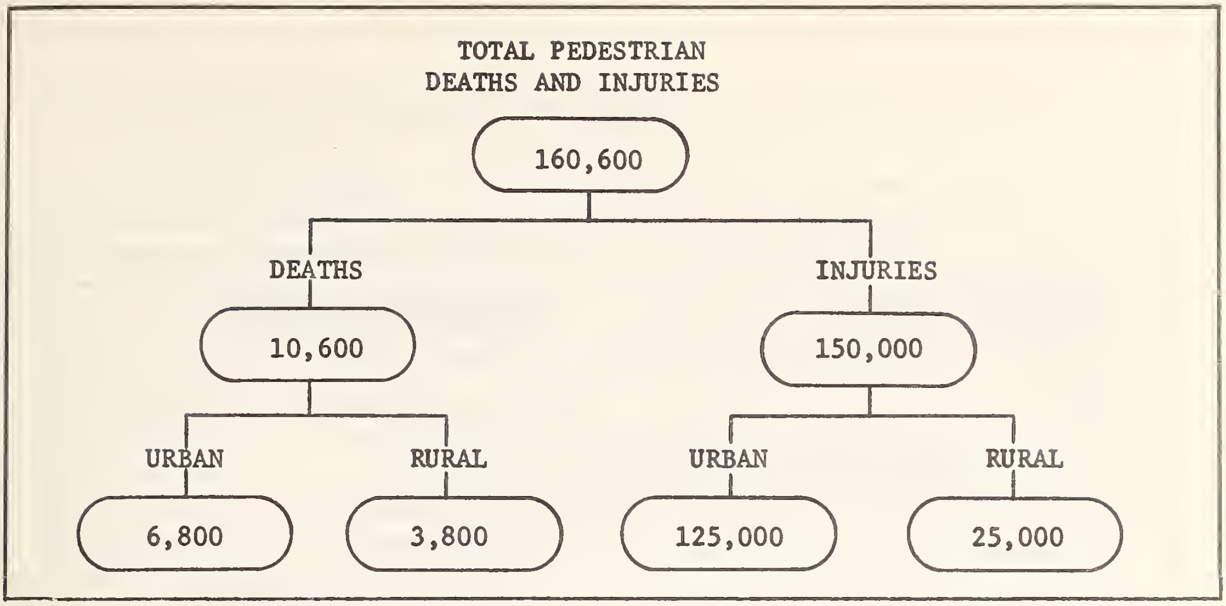

FIGURE 36

PEDESTRIAN DEATHS AND INJURIES - 1971

Source: Reference (1), Accident Facts, pg. 45.

	NUMBER OF ACCIDENTS
Motor Vehicle Collision With-	
Pedestrians	6,800
Other Motor Vehicles	5,700
Railroad Trains	400
Bicycles	450
Fixed Objects	1,950
Non-Collision	2,300
Total	17,600

TABLE 39

MOTOR VEHICLE DEATHS IN URBAN AREAS BY TYPE OF ACCIDENT - 1971

Source: Reference (1), Accident Facts, pg. 45.

PEDESTRIAN FACTORS

- Age
- Sex
- Physical and Mental Limitations
- Location Familiarity
- Driving Experience
- Movement Relative to Vehicle
- Presence of Alcohol or Drugs
- Crossing Volumes
- Visibility to Drivers
- Socio-Economic Status

ENVIRONMENTAL FACTORS

- Time of Day
- Day of Week
- Location
- Street Type
- Street Width
- Lighting, Illumination
- Weather Conditions
- Crossing Type (uncontrolled, etc.)

DRIVER FACTORS

- Age
- Sex
- Presence of Alcohol or Drugs
- Physical and Mental Limitations
- Driving Experience

VEHICLE FACTORS

- Speed
- Type
- Condition
- Traffic Volumes
- Movement Relative to Pedestrian

TABLE 40

GENERAL CAUSAL FACTORS IN PEDESTRIAN ACCIDENTS

5.1.3 The Safety Impact of Separation

The provision of facilities that separate pedestrian and vehicular movement tends to reduce pedestrian risk in proportion to the pre-existing risk associated with the crossing point prior to facility construction, and to the extent to which the facility is subsequently utilized. The risk incurred by a pedestrian making a single crossing using a grade-separated facility is zero because the potential for conflict at that point does not exist (note that in terms of a total trip, risk may be incurred at other conflict points); if the pedestrian chooses not to use the facility, the crossing risk remains approximately equal to the pre-existing risk at the crossing point: let this risk be denoted by R_B. Therefore, the combined condition of risk in the presence of a grade-separated facility is:

R_A = Pedestrian risk associated with a specific crossing;

$$= \begin{cases} O & \text{if facility is utilized for crossing} \\ R_B & \text{if facility is not utilized for crossing.} \end{cases}$$

For numerous pedestrian crossing trips, the average risk incurred per crossing will be the risks O and R_B, weighted by the extent of utilization, to give:

$\overline{R}_A$ = average pedestrian risk per crossing

$$= U \, . \, O + (1 - U) \, . \, R_B$$

where: U = fraction of all pedestrians that utilize the facility for crossing.

The absolute risk reduction is given by:

ΔR = risk reduction associated with facility utilization at a specific crossing point

$$= R_B - \overline{R}_A$$

$$= R_B - R_B + U \cdot R_B$$

$$= U \, . \, R_B$$

Hence, risk reduction is directly related to facility utilization and pre-existing risk; a similar formulation can be developed from the viewpoint of exposure reduction. The above expression is, of course, a simplification since utilization and risk are both functions of other variables. Many of the factors that influence utilization are discussed in Sections 5.2 and 5.3; several relevant factors affecting risk are discussed in the next section.

5.1.4 Selected Causal Factors

As shown in the previous section, risk reduction is related directly to the pre-existing risk associated with at-grade crossings at the point where the facility is constructed. Hence, the greatest impacts on risk reduction are going to be achieved when facilities are implemented at points of greatest risk (assuming adequate utilization). In this regard, several causal factors are particularly relevant to the impact of separation, namely crossing location, pedestrian and vehicular traffic volumes, and pedestrian age; these are discussed in the following sections.

Facility Location

Obviously, facilities should be implemented where the risk of pedestrian accident is high. Absolute measurement of safety impact can only be determined by analyzing in detail actual accident statistics on a before and after basis relative to facility implementation. The low incidence of pedestrian accidents and the lack of a controlled situation makes this an extremely difficult task, and may account for the fact that no research has been found which specifically addresses the safety impact of an in-place facility. Several studies have been made, however, which attempt to express pedestrian accident risk as a function of location. The results of these studies can give some clues to the relative impact of facilities and can serve as guidelines for planning.

1. Urban versus Rural: In terms of sheer numbers of accidents, pedestrian safety is primarily an urban problem. The fatality rate expressed as the number of deaths per 100 accidents is, however, higher in rural areas primarily because of higher vehicle operating speeds. Based on 1971 statistics,(1) the comparison is shown in Table 41.

	URBAN	RURAL	TOTAL
Number Killed	6,800	3,800	10,600
Number Non-Fatal Injuries	125,000	25,000	150,000
Total Killed and Injured	131,800	28,800	160,600
Fatality Rate	5.2	13.2	6.5

TABLE 41

PEDESTRIAN DEATHS AND INJURIES
URBAN VERSUS RURAL

Source: Reference (1), Accident Facts, pg. 45.

2. Urban Areas: The high risk areas for pedestrian accidents are in the center city outside the central business district. A relatively small percentage of all urban pedestrian accidents occur within the CBD.(2, 3) The highest risk areas appear to be located in the crowded residential areas bordering the CBD.(3) Table 42 illustrates the differentiation between CBD and surrounding areas.

3. Freeway Locations: In a California study of freeway accidents it was found that the majority of pedestrian accidents occurred when pedestrians were struck while crossing the freeway for the sole purpose of crossing.(4) This study also indicated that the number of pedestrian accidents was distributed equally between urban and rural areas, and that the accidents were widely scattered throughout the freeway system with no locations having a concentration of accidents. Major findings are summarized in Table 43.

ACCIDENT TYPE	PERCENTAGES BUSINESS AREAS (CBD)	 SURROUNDING CBD AREAS	 TOTAL
Fatalities			
At Intersections	3	40	43
Between Intersections	2	55	57
Total Percentage	5	95	100
Non-Fatal Injuries			
At Intersections	10	32	42
Between Intersections	4	54	58
Total Percentage	14	86	100

TABLE 42

PEDESTRIAN DEATHS AND INJURIES
CENTRAL BUSINESS DISTRICTS AND SURROUNDING AREAS

Source: Reference (2), AAA Manual on Pedestrian Safety, pp. 27-28.

	NUMBER	PERCENTAGE
Total All Pedestrian Accidents	416	100.0
Crossing Accidents - trying to cross	138	33.2
- hitchhiking and other	32	7.6
Total Crossing Accidents	170	40.8
Location - interchange area	63	37.1
- between interchanges	105	61.7
- unknown	2	1.2
	170	100.0
Interchange Accidents - barrier present	10	16.0
- no barrier	53	84.0
	63	100.0

TABLE 43

FREEWAY PEDESTRIAN ACCIDENTS

Source: Reference (4), Johnson, Freeway Pedestrian Accidents

Although each situation has to be evaluated in the light of a multitude of factors that can influence the safety impact of a facility, the above results suggest that:

- grade-separated CBD systems, in general, have only minimal effect on pedestrian safety due to the low number and probability of accidents;
- a large number of pedestrians are willing to take the risk of crossing heavy traffic flow on freeways between interchanges due to the inconvenience caused by long distances between interchanges; also barriers in the area of interchanges seem to have a beneficial effect; and
- areas most in need of reform due to high risk, such as older residential areas surrounding CBDs, should give more consideration to separation as a countermeasure to pedestrian accidents.

Vehicular and Pedestrian Traffic Volumes

Clearly, when vehicular traffic is light, pedestrians encounter very little delay, difficulty or risk in crossing roads or streets. However, as traffic flow increases, acceptable gaps between vehicles occur less frequently. As a result, the pedestrian is delayed. His impatience and inconvenience increase to the point that he may choose to take his chances on crossing even though gaps may not be adequate. When this happens, the risk of an accident increases accordingly.

The average delay to pedestrians is a function of traffic flow, street width, walking speed and vehicle speed. This subject is discussed in Section 5.2 under pedestrian convenience. The relationship between risk and traffic flow has been examined using empirical data in a study(5) conducted at the Road Research Laboratory (RRL) in Great Britain. Measures of risk were obtained for seven locations consisting of one- and two-way roads in four different towns. Risk is given by the expression:

$$\text{Risk} = \frac{\text{Accidents in 2-1/2 years}}{\text{Pedestrians crossing in 12 minutes}}$$

Obviously, this definition of risk is only useful in a relative sense, and has no meaning in absolute terms. It was sufficient to show, however, that risk does increase as traffic volume increases. The results obtained are shown in Figure 37. The interesting question of what happens for very heavy volumes of traffic still remains to be answered.

The results obtained in several other studies(6, 7) substantiate the relationship shown in Figure 37.

In a study of pedestrian risk in crossing busy roads in London(7), it was found that the risk decreased as a function of the number of pedestrians crossing and as a function of the pedestrian crossing density. This negative relationship was shown to be statistically significant.

Pedestrian Age

Pedestrian age is a significant factor due to its impact on both the level of risk and the economic and societal loss associated with pedestrian accidents. Simply stated, the young and the old have the highest risks of being involved in a motor vehicle-related pedestrian accident both from the standpoint of fatalities and non-fatal injuries. Numerous studies(1, 2, 5, 7) substantiate this relationship. This result has been shown to apply to all areas and to both sexes and is statistically significant(5, 7).

The death rate given by the number of pedestrian accident deaths per 100,000 population in each age group has a relationship to age as shown in Figure 38.

In a study of all accidents conducted by the U.K. Road Research Laboratory(5), relative risk for different age groups confirmed this relationship as shown in Table 44. The risk for the 16 to 60 age group was set equal to 1.0 to allow relative comparisons to the other two groups.

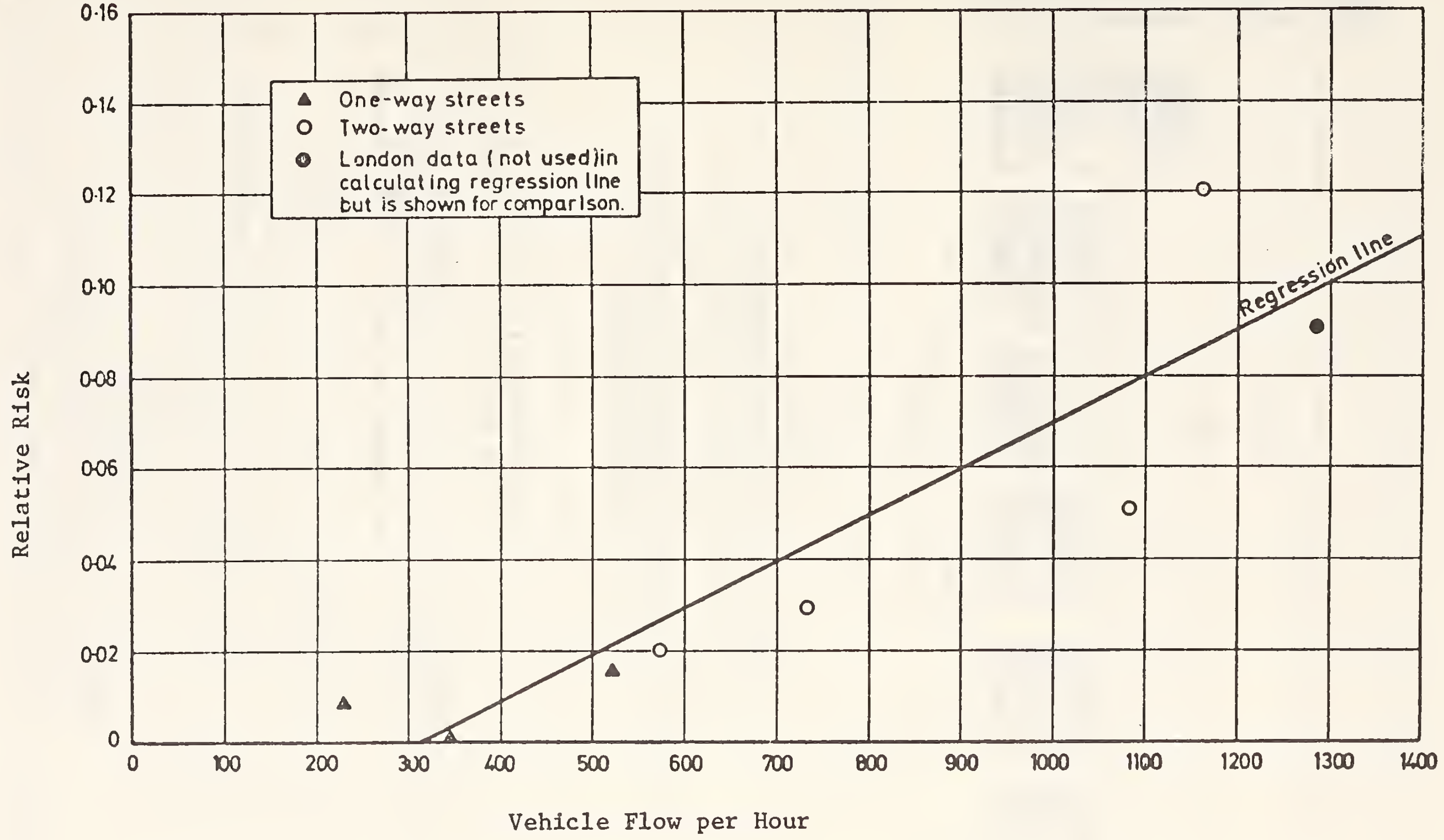

FIGURE 37

RELATIVE RISK VS. VEHICLE FLOW

Source: Reference (5), RRL Report LR 106, Figure 5.

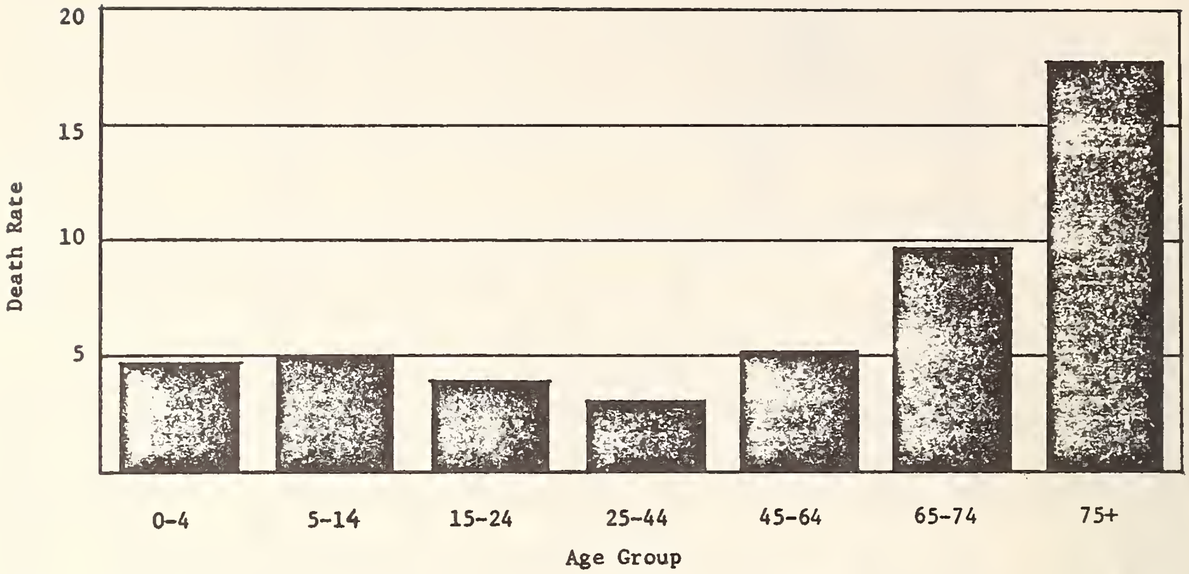

FIGURE 38

PEDESTRIAN ACCIDENT DEATH RATE VS. AGE

Source: Reference (1), Accident Facts, pg. 42.

AGE GROUP	RELATIVE RISK
0 - 15	4.29
16 - 60	1.00*
61 and over	3.59

* set equal to unity to show comparison

TABLE 44

RELATIVE PEDESTRIAN RISK VERSUS AGE

Source: Reference (5), RRL Report LR106, Table 8, pg. 11.

5.1.5 Cost of Pedestrian Accidents

A recent preliminary report by the National Highway Traffic Safety Administration (NHTSA)(8) places the estimated average societal loss of fatality resulting from a motor vehicle accident at $200,700 per person killed. The estimated average loss associated with a non-fatal injury is put at $7,300 per person injured. These figures cover all motor vehicle-related accidents.

There is reason to believe that the average losses for pedestrian accidents may be substantially higher than those above. Especially in the case of non-fatal injury accidents, the losses that accrue to pedestrians are likely to be higher. Note the differences in the rate of fatalities (fatalities per 100 accidents) as shown in Table 45.

	FATALITIES	NON-FATAL INJURIES	TOTAL	FATALITY RATE
Pedestrian Accidents	10,600	150,000	160,600	6.6
All M-V Accidents	54,700	2,000,000	2,054,700	2.7

TABLE 45

COMPARISON OF PEDESTRIAN FATALITY RATES WITH ALL MOTOR VEHICLE ACCIDENTS

Source: Reference (1), Accident Facts, pg. 45.

These fatality rate differences would suggest that pedestrian accidents are more severe than other types of motor vehicle accidents; this conclusion has also been noted in other more comprehensive studies.(2)

In computing the estimated average loss for non-fatal injuries, the NHTSA report uses the results of the 1969 national health survey to determine the number of injuries. These figures differ from those developed by the National Safety Council in that the national health survey injuries include all individuals who have experienced any activity restrictions due to injury(8). The National Safety Council injuries include only those persons disabled beyond the day of the accident.(1) The National Safety Council data represent a subset of more severe injuries within those developed by the national health survey. In a comparative computation to account for this effect, the NHTSA report obtains an estimated average cost of \$11,600 per person injured. This higher cost is probably more closely representative of the cost of pedestrian injury than the \$7,300 figure.

In Table 46, the cost of a fatality (\$200,700) and the assumed cost of non-fatal injury (\$11,600) are combined with 1971 National Safety Council pedestrian accident statistics(1) to obtain the estimated average costs of pedestrian accidents.

	PERCENT OF PEDESTRIAN		COSTS OF		WEIGHTED AVERAGE COST
	DEATHS	INJURIES	DEATHS	INJURIES	
Urban	5.2	94.8			\$21,400
Rural	13.2	86.8	\$200,700	\$11,600	\$36,600
Overall	6.6	93.4			\$24,100

TABLE 46

PEDESTRIAN ACCIDENT COSTS PER PERSON

Sources: Reference (1), pg. 45 and Reference (8), pg. 2.

Using data collected in predominantly urban areas, Smeed(9) has estimated the probability of a pedestrian accident per crossing to be approximately equal to 0.5×10^{-6}; this figure is in close agreement with similar results obtained by Cameron.(6) It should be emphasized that this estimate reflects data which was collected during daylight hours in urban areas characterized by medium to heavy volumes of vehicular and pedestrian traffic in European countries.

Using the estimated probability of pedestrian accidents per crossing of 0.5×10^{-6}, and the estimated average cost of an urban accident, the average cost per crossing is given by:

$\$A_U$ = approximate cost per crossing for pedestrian accidents in urban areas

$$= 0.5 \times 10^{-6} \frac{\text{Accidents}}{\text{Crossing}} \times \frac{\$21{,}400}{\text{Accident}}$$

$$= \$0.01 \text{ per crossing} = \$1.00 \text{ per 100 crossings.}$$

In other areas, changes in average cost of accident and risk will change the above estimate, but to some extent increase in cost may be compensated by decreases in risk so that the figure of a penny per crossing is probably a good gross estimate in most situations.

Finally, using figures from Table 45, the total estimated cost of pedestrian accidents in the United States in 1971 is:

(10,600 x $200,700) + (150,000 x $11,600)

or

$3.87 billion.

5.2 PEDESTRIAN CONVENIENCE

The importance that pedestrians place on convenience is manifest primarily in the way in which they are willing to forsake the safety of crossing at a signal-controlled location or via a grade-separated facility to endure the risks of crossing heavy vehicular traffic at points of great danger simply because it takes slightly less effort. This obvious indication of the high value placed on convenience by the person on foot points to the need for giving it serious consideration in the design, planning and implementation of pedestrian systems. Facilities for pedestrians should provide conveniences resulting from pathway directness, continuity and coherence not found on alternative paths; advantage should be taken of the natural delay and inconvenience that result when walking paths intersect vehicle flow, and if applicable, additional discouragements to further enhance utilization of pedestrian pathways should be provided.

In the following sections, pedestrian convenience is first discussed within the context of pathway impedance, followed by some aspects of the extent and cost of delays to pedestrians by vehicles. Convenience is then examined from the standpoint of the pathway itself in terms of the impact that pathway attributes such as directness and continuity have on pedestrian movement and pathway choice.

5.2.1 Pathway Impedance

Numerous studies have examined the distance that pedestrians are willing to walk. Obviously, most able persons will make short trips on foot. The added mobility alone often makes walking the most convenient means of transport over short distances. However, as distances increase fewer and fewer people choose to walk. Instead, another means of transportation will be used, or if that is too inconvenient, a decision will be made to not make the trip at all. This notion of the way in which the propensity to walk is attenuated with distance is illustrated in Figure 39 which represents a composite of walking trip surveys in the city centers of Seattle, Pittsburgh, Dallas, Denver, and Atlanta. Similar curves, often in the form of tables, were presented in Chapter 4 as representing the extent to which two centroids are separated.

As shown in Figure 39, the desire to walk distances exceeding a few hundred feet decreases rapidly. It is also interesting to note the application of relationships such as that shown to the planning or evaluation of pedestrian facilities. For example, a pedestrian overcrossing spanning a controlled access highway that reduces the mean walking distance from 1,000 feet to 500 feet is apt to be more effective than one that reduces distance from 1,500 feet to 1,000 feet. The former is more likely to create walking trips that previously were made by other means or not made at all than the latter. The pedestrian perceives a greater advantage of convenience, uses the facility and gives rise to a realization of attendant benefits.

The curve in Figure 39 is for illustration only. In most cases the application of this kind of information will have to consider the way in which this relationship is altered by such factors as trip purpose, location, pedestrian age, and so on. While even the smallest distance saving may significantly increase commuter utilization of the more efficient pathway, this improvement may be completely ignored by the shopper.

While it has been emphasized here for illustration, distance is certainly not the only variable in the propensity to walk decision. Certain alternative equidistant paths may be characterized by different walking times, and if perceived by the pedestrian tripmaker, could influence his pathway choice. When vertical change is required, especially stair climbing, impedance to walking is significantly increased. Other factors such as delays due to vehicles, discontinuities of direction, incoherence of signing, and simple unavailability of a

FIGURE 39

RANGE OF WALKING DISTANCES FOUND IN CITY CENTERS

Source: Reference (17), Levison, Derived from Figure 3, pg. 10.

pathway will affect the propensity to walk. While not necessarily independent of each other, all the factors act as impedances to walking and to the walking trip.

In a unifying sense, impedance can be closely approximated by the amount of energy required in making the walking trip. For example, the propensity to walk 1,000 feet up a steep grade will be less than that associated with a 1,000 foot walk on a level path due to the necessary difference in energy required. Delays at curbside due to vehicles, result in energy wasted, in effect, since it does not result in movement toward a destination. Pedestrian congestion due to inadequate pathway capacity acts in a similar manner.

Hence, when planning or evaluating walkways the relationship in Figure 40, basically similar to Figure 39 conceptually, should be kept in mind. The relationship between pedestrian convenience and other elements discussed is shown diagramatically in Figure 41.

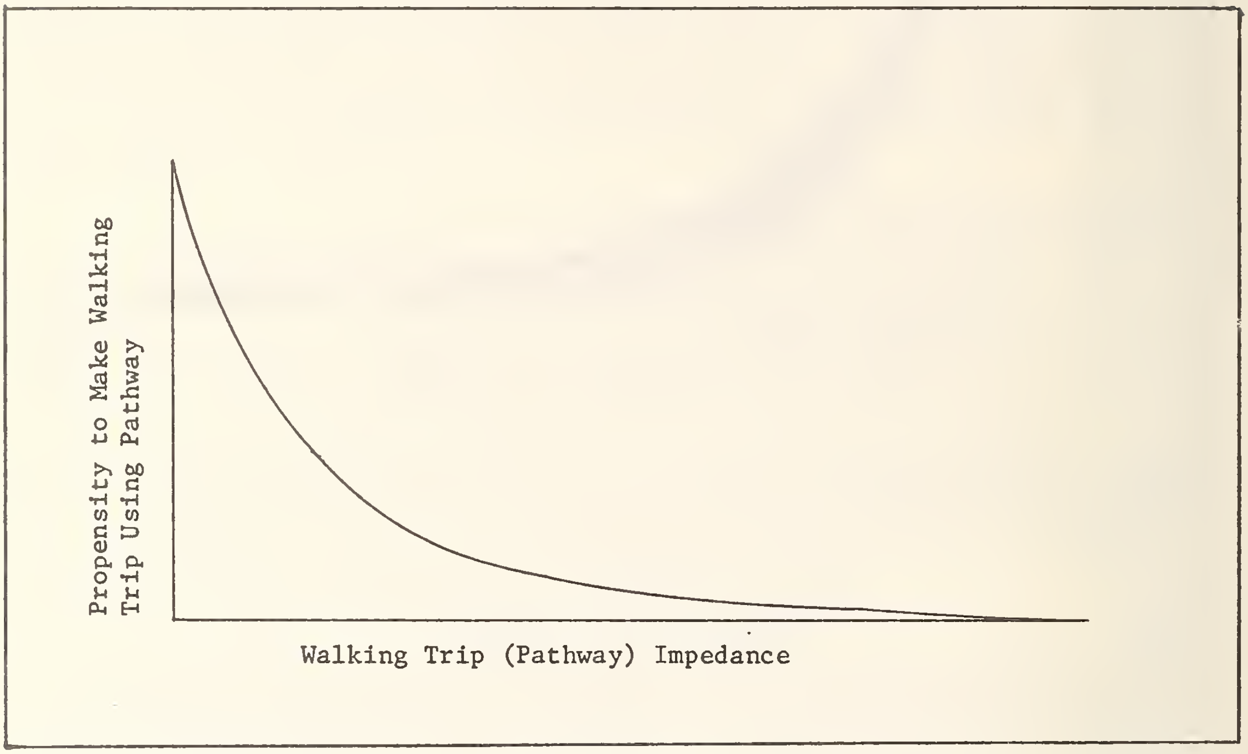

FIGURE 40

PEDESTRIAN TRIPMAKING VS. PATHWAY IMPEDANCE

5.2.2 Pedestrian Delays Due to Vehicles

During most pedestrian trips, one or more instances arise when it is necessary to cross the path of vehicular movement. In a large number of cases, this conflict, in addition to creating the potential for an accident, will cause some measure of pedestrian inconvenience due to the necessity to wait for an adequate gap in the traffic.

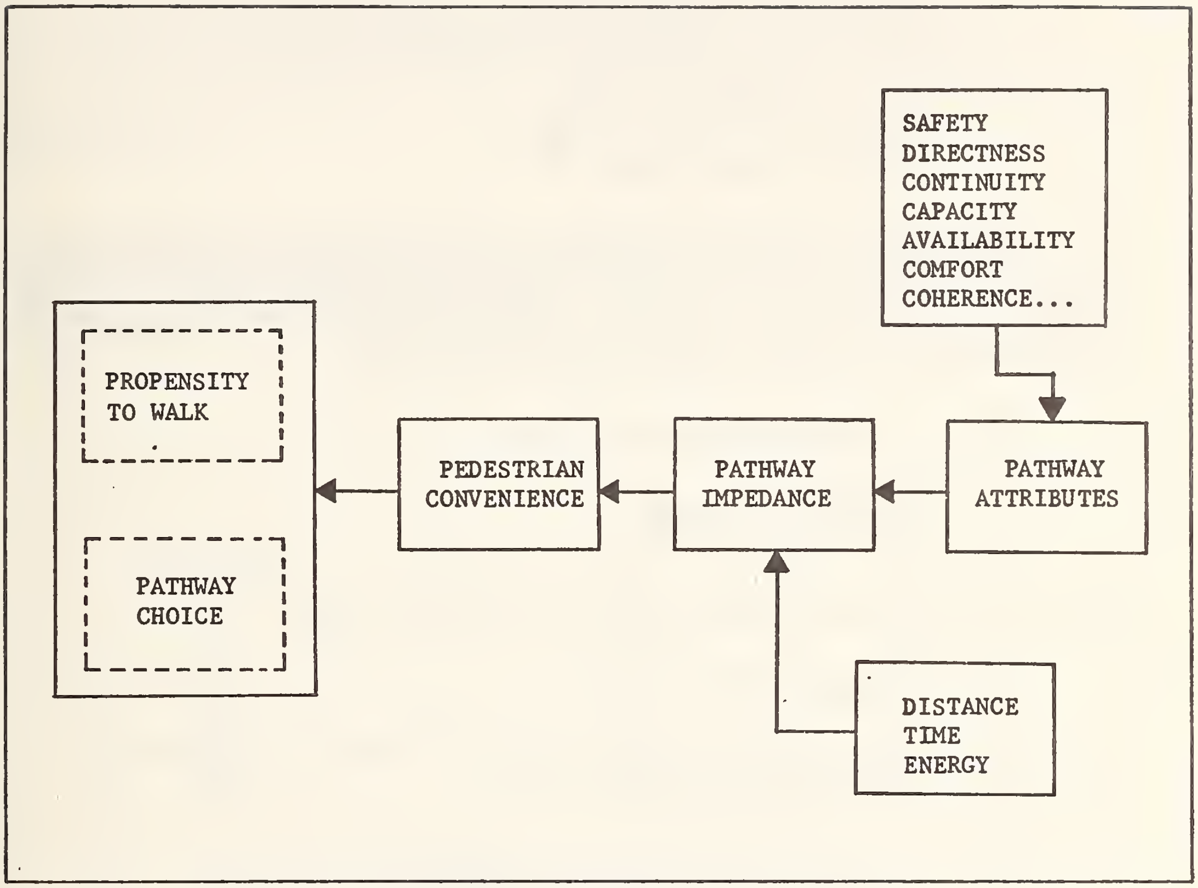

FIGURE 41

PEDESTRIAN CONVENIENCE AND RELATED ELEMENTS

The magnitude of the delay experienced will depend on a large number of physical and behavioral factors, such as:

- street or roadway width and type
- pedestrian walking speed
- pedestrian perception and reaction time
- size of pedestrian group
- type of controls present
- vehicle flow characteristics
- pedestrian risk taking.

Although research is limited, several studies have addressed the subject of pedestrian crossing delays. Assuming random traffic arrivals at uncontrolled crossings, Tanner(9) developed the following relationship for average pedestrian waiting time:

$\overline{w}$ = average pedestrian wait

$$= \frac{1}{N}(e^{NI} - 1 - NI)$$

where: N = one-way vehicle flow per unit time, and

I = crossing gap required.

The Traffic Engineering Handbook(10) gives the following expression for adequate gap time:

G = adequate gap time (in seconds)

$$= (w/3.5) + 3 + 2\,(N - 1)$$

where: w = critical width (in feet) of the crossing, and

N = number of rows of pedestrians crossing.

In the above equation, the first expression, $w/3.5$, represents the crossing time in seconds obtained by dividing the pavement width by 3.5 feet/second which is the assumed juvenile walking speed (this expression for gap time was developed for school crossings). Although the walking speed used in this equation is slower than that usually encountered in practice for pedestrians crossing in front of approaching vehicles (ranging from 4 to 6 feet/second)(11), it provides a desirable margin for children and the less agile or handicapped pedestrians. The second expression in this equation adds three seconds to the gap time to account for the perception and reaction time necessary to look both ways, make a decision and begin to cross. In the subsequent discussion that follows, this factor will be considered as part of the waiting time. Observations verify that pedestrians see the gap arriving and may actually start to cross before the last vehicle preceeding the gap has passed.(12) Finally, the last expression [2 (N - 1)] represents a two-second clearance time between rows of pedestrians.

Assuming representative roadway widths of 18, 24, and 36 feet and a pedestrian walking speed of 3.5 feet per second for a single pedestrian crossing where curbside reaction time is considered part of the waiting time, Tanner's formula gives rise to the array shown in Table 47.

VEHICLES PER HOUR	ROADWAY WIDTH (FEET)		
	18	24	36
500	3*	5	13
1000	6	14	49
1500	13	33	163
2000	25	73	544

* set to minimum value for perception and waiting since computed waiting time was less than 3 seconds

TABLE 47

REPRESENTATIVE PEDESTRIAN CROSSING DELAYS (IN SECONDS)

Given the limitations in the formulation used to generate Table 47 (namely, the assumption of random traffic and uncertainty in the behavior of the function as the independent variables approach upper and lower limits), the important conclusion to be drawn is that the probability of an adequate crossing gap decreases rapidly as a function of traffic flow and roadway width. The Traffic Engineering Handbook recommends 60 seconds as the maximum allowable delay as a warrant for crossing controls,(10) while Massey suggests that pedestrian impatience is evident after only 30 seconds.(12) It can be seen that these minimal delays are encountered only where the traffic flow is light to medium and roadway widths are restricted to approximately two lanes.

In an empirical study of pedestrian curbside delays where required gaps ranged from about 5 to 10 seconds depending on roadway width, Wilson and Older(13) obtained the relationship shown in Figure 42 for unmarked, uncontrolled crossings. The results shown in Figure 42 compare favorably with those computed using Tanner's equation.

5.2.3 The Cost of Pedestrian Delay

In Section 5.1.5, a rough approximation of the cost of pedestrian accidents was estimated to be $0.01 per crossing (or $1.00 per 100 crossings). For purposes of comparison it would be interesting to have an estimate of the cost of pedestrian curbside delay resulting from vehicular flows.

The delay cost will depend on two factors: average pedestrian delay and the value of pedestrian time. Conditions vary so widely that it is not possible to estimate these factors with any acceptable degree of confidence. In practice, each situation should be studied in isolation. In this section, however, a gross approximation on the upper limit of the cost of pedestrian delay will be obtained simply for the purpose of estimating the order of magnitude of the cost.

An upper bound on the average delay per pedestrian crossing is suggested by the empirical results presented in Figure 42. Since these results represent urban settings where delays are apt to be at their maximum, an upper bound of about 15 seconds per crossing would appear to be reasonable. In consideration of the value of pedestrian time, the value of walking time related to peak hour commuters provides a reasonable upper bound. A 1967 study by Lisco(14) establishes the value of peak hour walking time for commuters in the Chicago Loop area at $2.40 per hour* (for commuters with an average annual income of $8,000). Adjusting the commuter value of 1972

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*Unit value delay cost is used here and elsewhere only for exemplary purposes. Other values may be more appropriate, as shown in The Value of Time Saved by Trip Purpose, by T. C. Thomas & G. I. Thomson, Stanford Research Institute, 1970. Estimates are presented of the value of travel time savings as a function of three factors: absolute amount of time saved, income level, and trip purpose. For any specific street and traffic situation, a frequency distribution of the three factors may be employed to compute a weighted average delay cost.

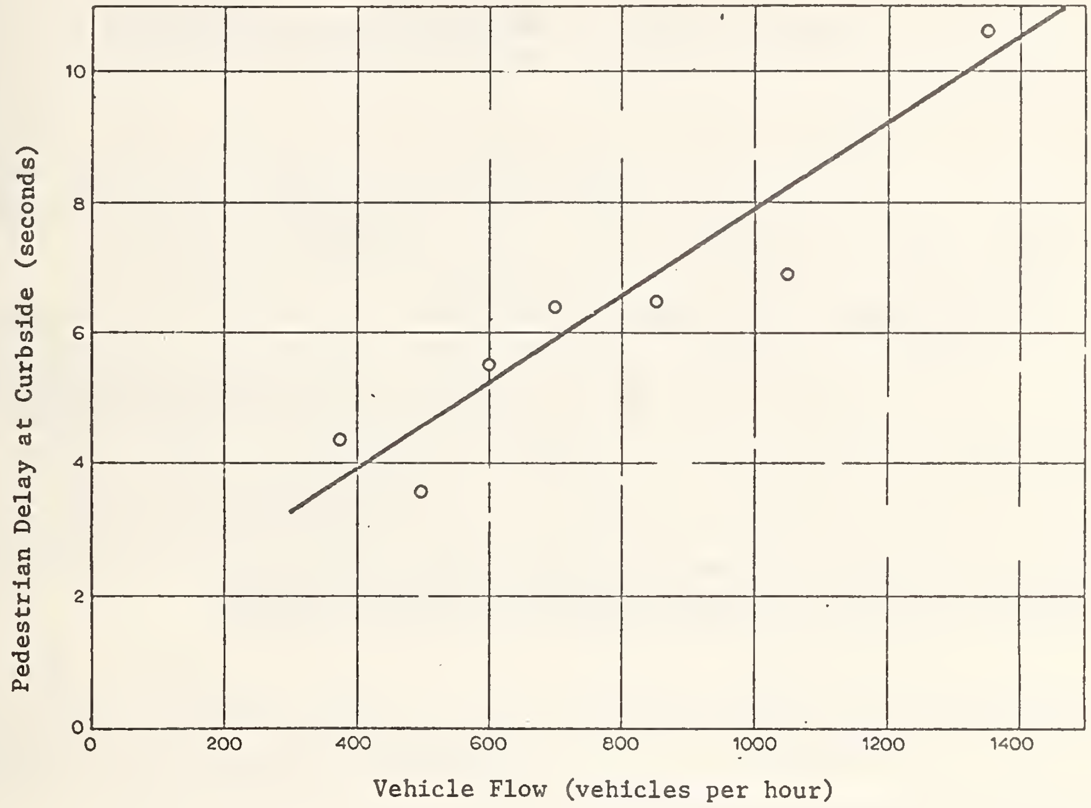

FIGURE 42

PEDESTRIAN DELAY VS. VEHICLE FLOW

Source: Reference (5), RRL Report LR 358, Figure 8.

dollars on the basis of non-agricultural hourly wage indices (1967 = \$2.68, 1972 = \$3.65) gives a value of \$3.27. Using the upper limits of 15 seconds average delay and \$3.27 value of pedestrian time, the following computation can be made:

(\$D) = estimated upper limit on the cost of pedestrian delay per 100 crossings

$$= (100 \text{ crossings}) \times \frac{15 \text{ seconds}}{\text{crossing}} \times \frac{\$3.27}{3600 \text{ seconds}}$$

$$= \$1.36$$

On this basis, it would appear that the cost of pedestrian delay is of the same order of magnitude as the cost of pedestrian accidents.

5.2.4 Convenience and Pathway Attributes

In addition to being a threat to safety, vehicle flow represents an impedance to pedestrian movement, but it is not the only element that impedes his progress from origin to destination. Various pathway attributes, depending on degree, act as impedances along the pedestrian trip; when alternative paths exist, the pedestrian is apt to choose the one he perceives to represent the lowest level of impedance. The major attributes impacting upon his convenience are:

- directness,
- continuity,
- capacity, and
- availability.

When considering a planned pedestrian environment, special attention must be given to the pathway attributes cited above in order to ensure adequate utilization of the pedestrian system; otherwise systems will not be used. It has been shown that grade-separated facilities may not be used even when they offer convenience benefits to pedestrians; this points to the need for enhancement of the pedestrian accomodations coupled where applicable to a discouragement of other pathways.

Directness

Directness is a measure of pathway impedance related to the time, distance or effort that is required to use a pathway connecting two given centroids. Studies have shown that the use of alternative paths is related to the actual or perceived extent to which each pathway "separates" two connecting points in terms of time, distance or energy. When one path offers the pedestrian a savings in terms of these measures, it is apt to be used in favor of one which requires additional effort, even when the latter provides a safer route. Directness can be viewed as one component of pathway impedance or separation between points; others such as discontinuities and congestion are discussed in other sections. Directness is used to describe the extent to which a pathway deviates from the most direct alternative pathway.

In an absolute sense the most direct route is one which coincides with the vector connecting two points in space. As a planning consideration, it may be useful to examine a pathway on the basis of this relationship to its minimal spatial separation as given by:

$$D_{max} = \text{measure of the maximum directness between two centroids}$$

$$= \frac{\text{minimal spatial separation between centroids}}{\text{distance measured along the pathway between centroids}}$$

D_{max} has an upper limit of 1.0 when the pathway distance is equal to the spatial separation, and decreases toward zero as the distance along the pathway increases.

The importance of directness as a pathway attribute was shown in an examination made by the Road Research Laboratory (U.K.) of pedestrian movement across a section of roadway before and after installation of a pedestrian underpass.(11) Before construction of the underpass, it was determined that 41% of pedestrian crossings within a specified section of roadway were made at a single point. After an underpass was constructed at this point of maximum crossing density, the facility was used by 50% of those crossing the roadway, but an additional 5% of the pedestrians still chose to cross at-grade in close proximity of the underpass. Hence the facility was able to attract only about 9% additional utilization over the hazardous at-grade routes. The conclusion reached by the researchers was that when the facility route closely followed the desired pedestrian path — which usually coincides with a direct line-of-site — most people were willing to use the safe route; but when only a slight extra effort was required, few people used the facility.

In a generalized form, directness can be expressed by the following relationship:

D_{ab} = the directness of path a relative to path b (where both paths connect the same two centroids)

$$= \frac{S_a}{S_b} = \frac{\text{impedance measure of path a}}{\text{impedance measure of path b}}$$

The above general equation implies pathway impedance as measured by distance, time, energy or other applicable values.

In another Road Research Laboratory study, approximately thirty pedestrian bridges and underpasses were examined.(11) At each site, individual pedestrians were selected, their journeys timed, and a record made of their crossing route — either via the grade-separated facility or via an alternative at-grade route. The study results were then used to compute a statistic, R, similar to D_{ab} as given by the expression:

D_{ab} = R = directness of a specific pedestrian route (versus an alternative at-grade route)

$$= \frac{\text{crossing time via grade-separated facility}}{\text{crossing time via alternative at-grade route}}$$

The measure, R, was then averaged for each facility and related to a measure of pedestrian facility utilization as given by:

U = percentage of pedestrians using the facility

$$= \frac{\text{number crossing roadway via facility}}{\text{total number crossing the roadway}}$$

Values of R and U were then plotted resulting in the relationship shown in Figure 43.

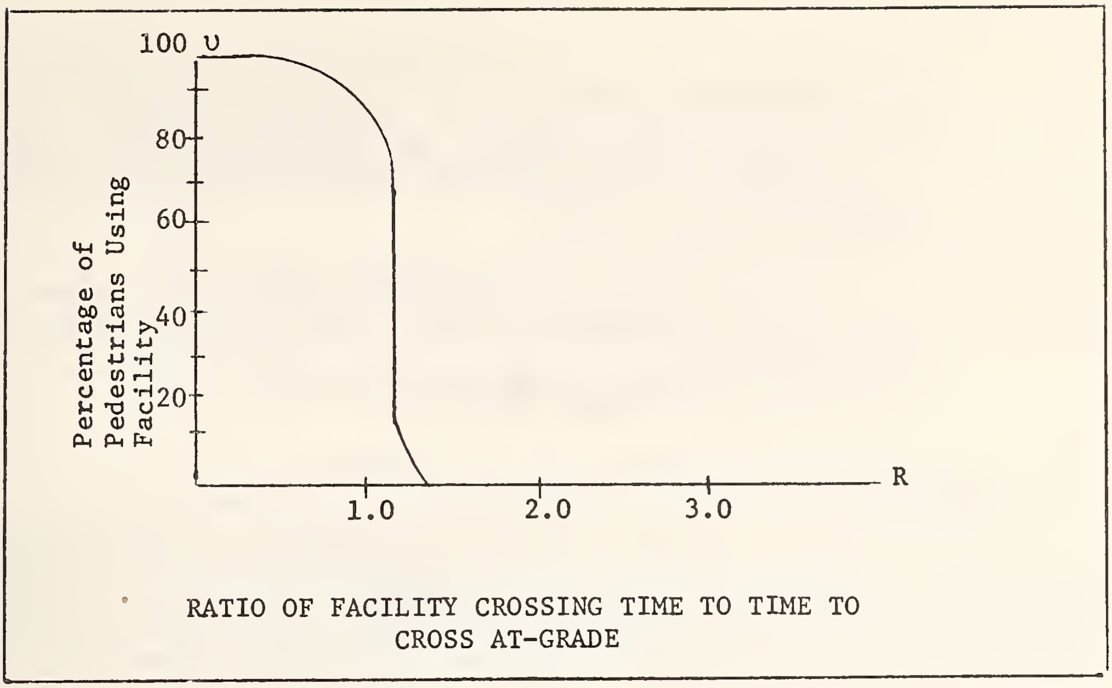

FIGURE 43

FACILITY UTILIZATION VS. DIRECTNESS

Source: Reference (3), Moore and Older, Figure 8.

Several comments are in order regarding the relationship shown in Figure 43.

- Utilization was clustered in the ranges above 63% and below 15% which suggests that pedestrian route choice was unambiguous--one or the other paths was perceived by most pedestrians to be superior.

- In a division of facilities by type, underpasses generally showed higher utilization rates than bridges for comparable values of R--these results have to be tempered by possible related factors which are unknown, such as time of day, facility location, level of pedestrian activity.

- Even when the facility offered the same measure of directness as the at-grade route (R = 1.0), approximately one in five pedestrians still chose the unsafe route; this points to the perceived impedance path discontinuity or a requirement for vertical change.

- The importance of discouraging the use of unsafe routes is obvious from the diagram; obstructions such as barriers and fences along the at-grade route would reduce R to a value conducive to high utilization.

Continuity

Continuity is an attribute which expresses the extent to which a given pathway between two points is interrupted by vehicular conflicts, vertical changes, turning movements, directional decision points and similar elements, all of which add to the pathway impedance and increase the separation of the centroids. Note that continuity may be, but is not necessarily, related to directness. A pathway may be absolutely direct — connecting two points by a path along the line-of-sight vector between them—but may involve one or more conflicts with vehicular movement thereby degrading the continuity of pedestrian movement. On the other hand, a path which involves numerous turns will probably rate poorly with regard to both directness and continuity — the two measures being related through the number of turns in the pathway configuration. Vehicular conflict usually introduces time delay into the pedestrian trip. Vertical movement usually requires more time and energy than horizontal movement without the same reduction in trip length. Turns and decision-making associated with changes in direction along a pathway introduce impedances to continuous pedestrian movement.

The impact of continuity was examined for pedestrian trips in the Toronto central business district. (15) A gravity model formulation was developed to predict and analyze pedestrian movement patterns. In calibrating the models in an effort to replicate actual counts of pathway volume, it was necessary to introduce several elements of pathway discontinuity into the measure of centroid separation used in the model. The relationship that was found to produce results in the model which matched actual experience was:

d = measure of separation (in minutes) used in the Toronto CBD gravity model

$$= t + 0.5\,w + 0.4(t \quad A) + 0.01 \quad T$$

where: t = average walking time along the pathway

w = average waiting time along the pathway

A = attractive time of trip (a measure of the portion of the trip related to attractive features abutting the pathway)

T = number of turning movements

It can be seen that waiting time (delays) and turning movements act as impedances along the pathway thus increasing the separation. This increased separation would tend to reduce the pathway pedestrian volumes. The expression, $0.4\ (t - A)$, adds an element of separation to account for the unattractive part of the trip which acts as a pathway impedance affecting pedestrian movement; this is discussed under the section on pathway interest.

A second confirmation that discontinuity degrades pathway utilization is provided by Figure 43 which shows that pedestrians perceive vertical change inherent in most highway crossing facilities as an impedance even through the actual time to cross via the facility is less than the at-grade route. Note that when $R = 1.0$ (pathway trip times are equal), only about 80% will choose the safer route offered by the facility; the other 20% will continue to use an unsafe route.

The impact of pathway continuity will vary according to trip purpose. The Toronto model's measure of separation applied primarily to office worker lunch hour trips where definite constraints on walking and waiting time exist. For the ordinary shopper, the equation shown above would probably change to the extent that the coefficients would be different, or other factors would replace or be added to those shown; some discontinuity and irregularity could provide an element of interest to shopper or casual stroller. On the other hand, commuter trips such as trips to work, and all terminal trips would be greatly affected by pathway discontinuity.

Vertical discontinuities, particularly as they relate to grade-separated pedestrian facilities, require special attention. Numerous researchers have noted the negative impact of vertical change on pedestrian behavior. Stairways are the major problem. Pushkarev and Zupan (20) have noted that people will wait in queue for 2 minutes to use an escalator simply to save the effort of climbing 20 feet of stairs. Where space permits, ramps are preferred to stairways since they are safer and easier to use.(21) Escalators, and possibly elevators, would generally be preferred over both stairs and ramps due to the saving in effort.

Of the three major means of effecting grade changes along pedestrian pathways, the intuitive order of desirability is:

- escalators
- ramps
- stairs

The central question is what is the relative impedance or disutility for the three. Stairs are undoubtedly the major problem. Although they are the most studied, still very little is known. (22) Studies of energy consumption, a clue to the relative impedance or disutility, have so far been inconclusive. (22)

Recent studies indicate that the rated capacities of stairs and escalators are grossly over-estimated. Desired flow on New York subway stairs is about 2 persons per foot width per minute rather than the standard of 16 used for design. (20) For escalators, general usage is about 18 pedestrians per minute per foot with a maximum of about 30 — far below the range of 40 given by the manufacturers. (20)

Capacity

Pathway capacity is an essential factor influencing pedestrian movement and convenience, and in turn facility utilization. If capacity is inadequate, pedestrians — especially during peak hours — become crowded, movement is impeded, walking speed slows, trip time increases, physical discomfort occurs and in general, the walker is inconvenienced. Instead, pathways should reflect a balance between capacity and convenience so that pedestrians can maintain reasonable walking speeds and maneuverability. When this is possible, impedance is reduced and pathway utilization enhanced by the pedestrian's own perception of the pathway's benefits.

A considerable amount of attention has been given to the subject of pathway capacity.(16-19) In particular, Fruin(19) has examined the relationship between walkway capacity, and pedestrian walking speed and convenience. Time-lapse photographic studies of pedestrian flows were analyzed to obtain measures of pedestrian volumes and densities over defined sections of various pathways. In contrast to earlier studies, Fruin uses the reciprocal of density--named the pedestrian area module in square feet per pedestrian — as a measure of the quality of service (i.e., pedestrian convenience) provided by the walkway.

Using the photographic study results, and the relationship between capacity, speed and the pedestrian area module as given in Figure 44, Fruin develops the results shown in Figures 45 and 46.

P = MEAN FLOW RATE OR VOLUME (IN PEDESTRIANS PER FOOT OF WALKWAY WIDTH PER MINUTE)

= S/M

where: S = mean walking speed (in feet per minute), and

M = pedestrian area module (square feet per pedestrian)

FIGURE 44

FUNDAMENTAL PEDESTRIAN TRAFFIC FLOW EQUATION

Source: Reference (19), Fruin, page 2.

In a supplementary study, Fruin also determined the effects of the pedestrian area module on the potential for conflict when pedestrians cross an opposing stream at right angles. Conflicts were defined as any adjustment to speed and/or direction to avoid colliding with another pedestrian. The results of this analysis are shown in Figure 47.

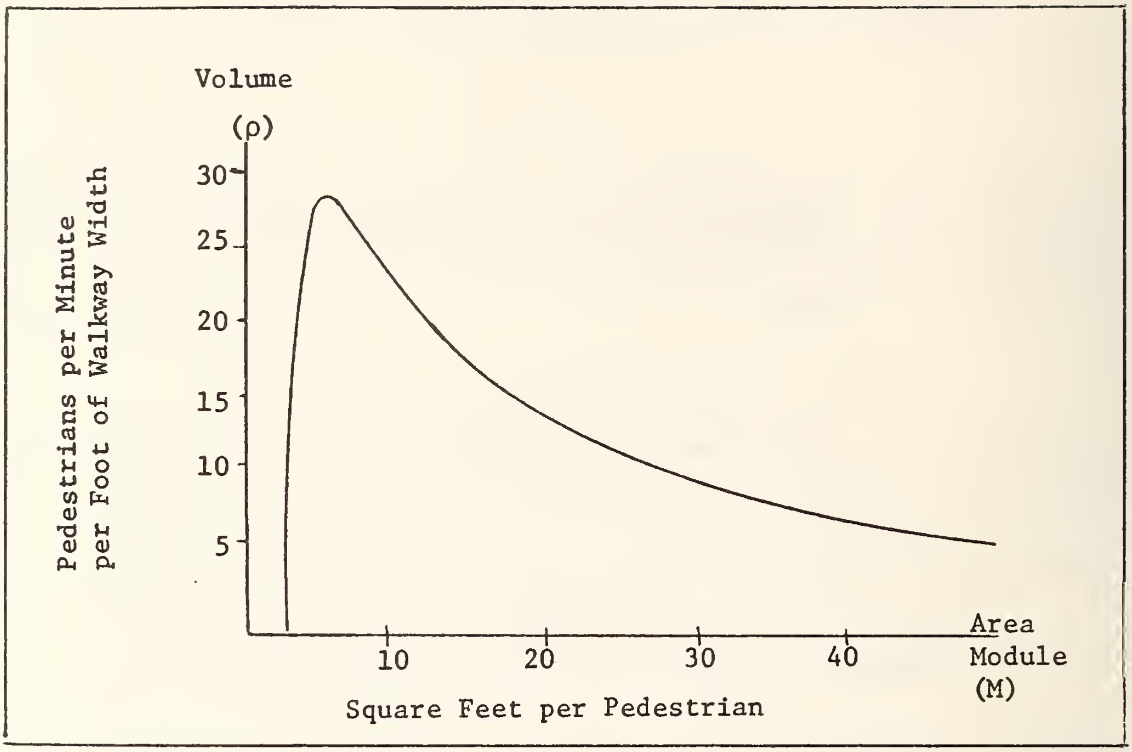

FIGURE 45

PEDESTRIAN VOLUME VS. SPACE FOR WALKING
(Undirectional Pedestrian Traffic Flow)

Source: Reference(19), Fruin, Figure 1, page 3.

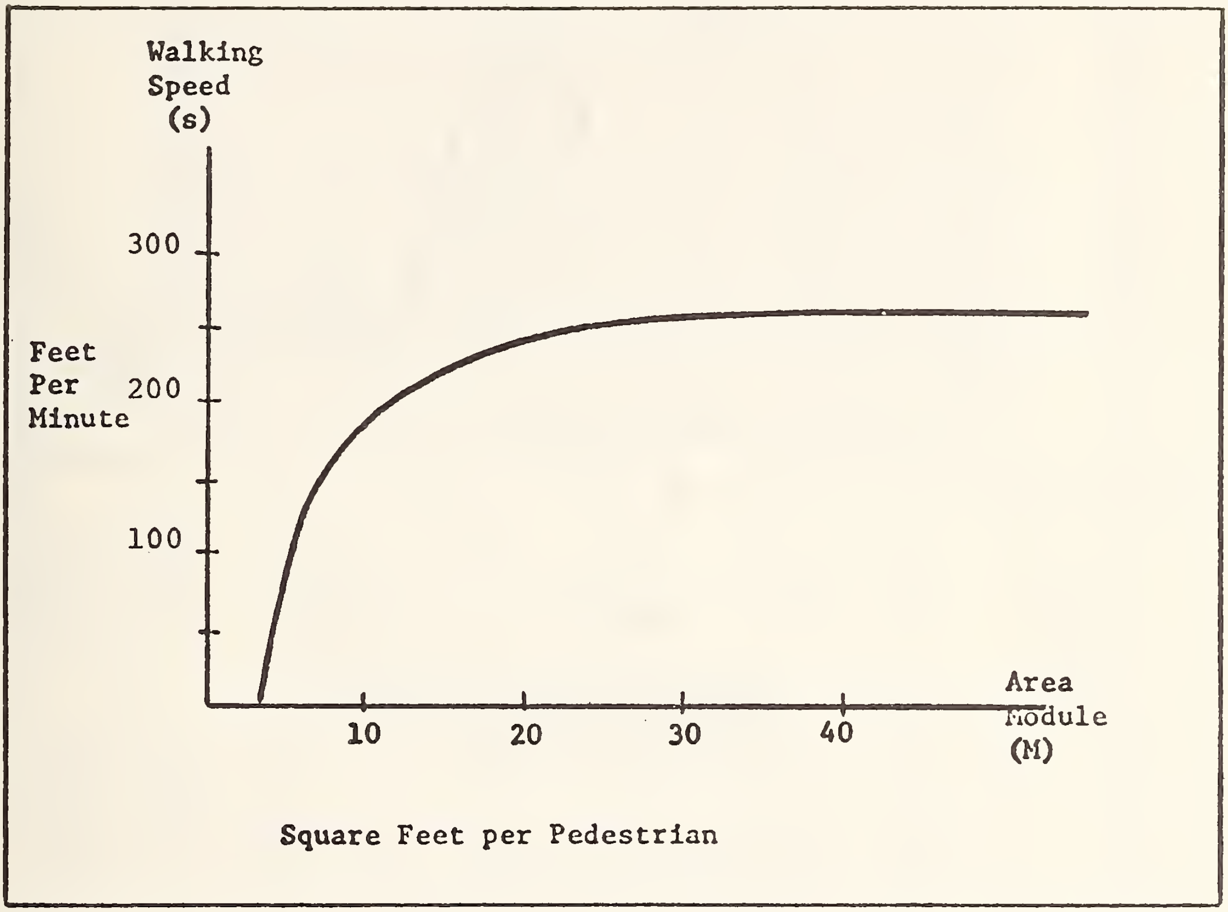

FIGURE 46

PEDESTRIAN SPEED VS. SPACE FOR WALKWAYS
(Unidirectional Pedestrian Traffic Flow)

Source: Reference (19), Fruin, Figure 2, page 3.

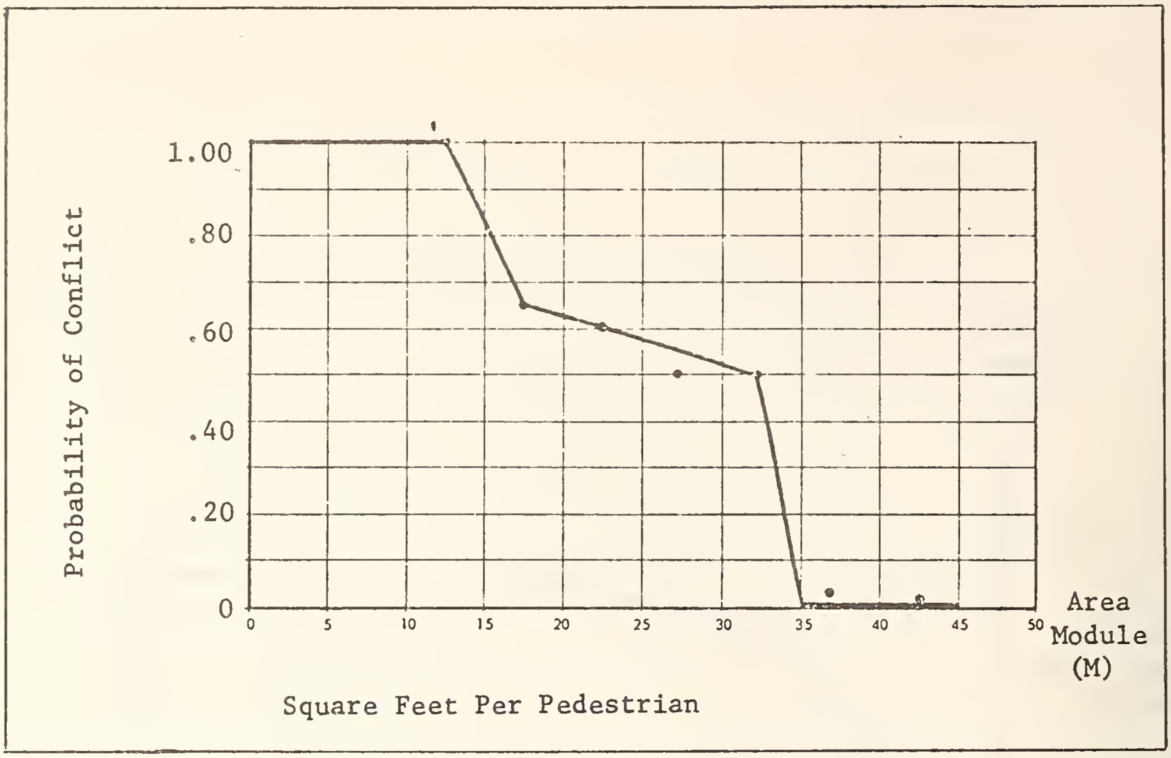

FIGURE 47

PEDESTRIAN CONFLICT VS. SPACE
(Pedestrian Traffic Streams
at 90° Opposition)

Source: Reference (19), Fruin , Figure, page 5.

Using the results summarized in Figures 45, 46, and 47, Fruin has developed a structured concept of the relationship between walking capacity as expressed in terms of the pedestrian area module and pedestrian convenience as it relates to walking speed, potential for conflict and similar factors. Selected elements of this concept are shown in Table 48. The obvious conclusion to be drawn from Table 48 is that walking speed and the potential for movement conflict and physical contact are impedance factors which depend directly on pedestrian densities. In terms of pathway choice, other things being equal, pedestrians are likely to choose the pathway which adequately provides the ability to choose walking speed and avoid conflict.

PEDESTRIAN AREA MODULE (square feet per ped.	WALKWAY CAPACITY (pedestrians per foot width of walkway per minute)	IMPACTS ON PEDESTRIAN CONVENIENCE		
		PEDESTRIAN WALKING SPEED (feet per min.)	PROBABILITY OF CROSSING CONFLICT	CONVENIENCE-RELATED CHARACTERISTICS
35 and above (level A service)	Approximately 5 to 7	Maximum 260 - 270	Minimal Near Zero	. Any walking speed can be selected . Slower pedestrians can be passed . Cross- and counter-flow conflict is avoided
25 to 35 (level B service)	7 to 10	250 - 260	Near zero to 60% at 25 sq. ft. per ped.	. Normal walking speed can usually be maintained . Passing in unidirectional flow is possible . Only minor cross- and counter-flow conflict is encountered
15 to 25 (level C service)	10 to 15	235 - 250	60 to 80%	. Walking speed somewhat restricted . Maneuverability is hampered particularly in multidirectional flow . Contact is avoided only by frequent changes in speed and direction
10 to 15 (level D service)	15 to 20	200 - 235	80 to 100%	. Walking speed restricted and reduced . Bypassing severely restricted . Multiple conflict occurs in both reverse flow and crossing movements
5 to 10 (level E service)	20 to 25	110 - 200	100%	. All walking speeds restricted . Bypassing cannot be accomplished . Reverse-flow and cross-flow movements extremely difficult
Less than 5 (level F service)	Severely limited	120 or less	100%	. Movement primarily by shuffling . Bypassing cannot be accomplished . Contact unavoidable, reverse and crossing movements impossible

TABLE 48

CHARACTERISTICS OF WALKWAY CAPACITY VERSUS PEDESTRIAN CONVENIENCE

Source: Reference (19), Fruin, pp. 7-8

Availability

In order to be effective, pathways have to satisfy the requirements of the pedestrians who want to use them. Two major elements of pedestrian facility availability are:

- facilities should be available when they are needed, and
- facilities should be available to all pedestrians who want to use them.

In the first case, facilities that depend on the operation of abutting properties will automatically have a restricted availability. In the second case, the absence of consideration for the movement of aged or handicapped persons will restrict utilization of the facility by these groups of pedestrians.

Ideally, pedestrian walkways should be in the public domain and available at all times. Where pathways abut or penetrate private property such as links through interior arcades, however, it is often necessary to make availability suit security requirements for the private spaces. Similarly, it may be necessary to provide locked gates to restrict utilization of some pedestrian highway underpasses at night because of potential problems. Nevertheless, where possible, facility availability should be matched to demand for its use, and adequate attention should be given to the nature of related pedestrian movement to ensure that availability is consistent with need. A study of pedestrian activity in midtown Manhattan(23) provides a picture of time-dependent pedestrian movement related to four basically different activity types for a large metropolitan area; a simplified summary from this study is shown in Table 49.

The indication from Table 49 is that walkways serving residences and activities such as restaurants, theaters, and sports arenas should be available during evening hours if possible. In certain instances, department stores and other retail activities might benefit by added exposure to window-shopping strollers, especially when other activity exists in the area.

BUILDING TYPE	12-HOUR STUDY PERIOD	APPROXIMATE PERCENTAGE OF TOTAL DAILY PEDESTRIAN TRAFFIC
Office	7:30 am - 7:30 pm	99
Department Store	9:00 am - 9:00 pm	100
Restaurant	9:00 am - 9:00 pm	80
Resident	7:30 am - 7:30 pm	70

TABLE 49

LEVELS OF DAYLIGHT PEDESTRIAN ACTIVITY

Source: Reference (23), Pushkarev and Zupan, pg. 43.

5.3 COMFORT AND OTHER IMPACTS

The preceding sections in this chapter have dealt with the importance and impact of safety and convenience in the design and implementation of pedestrian systems. From the point of view of the pedestrian himself, however, walking is affected by many other factors that cannot be classified as safety or convenience. As Maring has reported, (24) when asked to rank factors that discourage walking, respondents ranked crime first, followed by unfavorable weather. Numerous other factors such as pollution, lighting and health were also noted in varying degrees of importance. Notwithstanding the possible bias due to location inherent in the Maring survey, the key issue is that in order to be effective, pedestrian systems must be able to provide the pedestrian with more than safety and convenience. Obviously, he must be given security and protection from the extremes of environment, but he must also be provided with a coherent system that does not cause unnecessary anxieties, and one that is interesting and pleasant. These factors are discussed in the following sections.

5.3.1 Security

Despite all other advantages that may be realized by pedestrians using systems designed for them, it is probable that they will still feel more secure at night walking along a street where there is apt to be some form of activity than on a deserted walkway.(25) Darkness is almost universally recognized as an impedance to walking, especially in large urban centers. To many people it is the greatest discouragement to walking.(24)

Maintaining security is often cited as the main problem with pedestrian underpasses. It appears that long pedestrian tunnels like highway underpasses and those found in many subway systems have all the poor security-related characteristics that discourage utilization. For example, they are:

- subject to vandalism and criminal acts since surveillance and policing are difficult;
- usually narrow in comparison to their length giving users a feeling of confinement;
- apt to be poorly lighted and uninviting; and
- often characterized by poor sightlines to exterior centers of activities which further detracts from their use.

If walkways are to be designed for 24-hour use, which is essential when connections exist to train stations, subways and similar terminals, and to a lesser extent when late-night activities such as theaters, restaurants and hotels connect to the system, then it will be necessary to give special attention to the provision of adequate security. Sight lines to other centers of activity should be carefully considered, lighting should be used to discourage illegal acts, and adequate surveillance and policing provided.

5.3.2 Environmental Protection

As noted in the introduction to this chapter, people may view unfavorable weather as second only to crime as a factor that discourages walking. Intuitively, the provision of cover or closure will encourage walking by providing pedestrians with the comfort and benefit of some degree of climate control, and by providing retail merchants with pedestrian traffic that would probably not exist at all if some protection were not provided. Obviously, the provision of environmental protection has to be balanced against need. In mild, arid climates the need for cover or closure diminishes. In the vast majority of urban settings, however, precipitation and extremes in temperatures will create the need for some form of protection. Noise and air pollution should also be considered.

Environmental protection is important for several reasons:

1. pedestrians naturally desire protection from environmental extremes;
2. retail shopping activities of pedestrians can be affected by the weather;
3. risk of accident increases in inclement weather;
4. protection provided for extremes in weather can also improve the pedestrian environment with regard to noise and air pollution.

On the first point, the manifest desire of pedestrians for protection against the elements has been documented in several studies. In particular:

- Lovemark has reported that a drop in temperature from 77°F to 23°F will reduce the number of shopping pedestrians by 50%;(26)
- under similar conditions, pedestrian business trips will be reduced by 25%;(26)
- a light rain (1 mm/hr) has effects similar to the temperature drop noted above; (26)
- in Manhattan where it rains approximately 11.2% of the daylight hours (and is uncomfortably hot or cold about 22% of the time), pedestrian flow on surface street is reduced 25-30% when it rains - much of it being diverted underground where practical; (27)

- underground entries into the New York Port Authority bus terminal experience a 40% increase in pedestrian volumes on rainy days; (27) and

- pedestrian counts on the totally enclosed and climate controlled skyways of the Minneapolis system show the effects of weather as shown in Table 50.

In Table 50 the consistency of the counts on the first three, high-utilization, days when the weather was mostly warm and sunny contrasts with the abrupt volume increases when the weather was rainy and cold and to the somewhat lesser increases in hot and humid weather, suggesting that comfort has a very definite positive impact on pedestrian utilization of climate-controlled facilities.

As the above results show, pedestrians do desire to be protected against the weather. The following discussion extends this to show that not only will the number of potential shoppers be reduced because of weather, but that the nature of the shopping activity may be adversely affected.

In a study of pedestrian travel rates in the Pittsburgh central business district, Hoel obtained the following results:(27)

- In a detailed study of 135 individual pedestrian trips, Hoel showed that the pedestrian travel rate was influenced by the type of land use abutting the pathway. A single typical observation is shown in Figure 48. Hoel notes that other possible conditions such as type of walking surface did not affect the rate.

- Variations of pedestrian travel rate by time of day were noted. The mean rate between 8:00 a.m. and 9:00 a.m. was 4.92 feet/second which is consistent with the dominant unidirectional commuter movement encountered during that period. Between 1:00 p.m. and 2:00 p.m., the mean rate decreased to 4.45 feet/second characterizing the mixture of business and shopping movement of this period.

- A study of the variation of pedestrian travel rates as a function of ambient temperature produced the result shown in Figure 49.

SKYWAY	DAILY PEDESTRIAN COUNTS					
	TUESDAY 6/23/70 SUNNY AND WARM	FRIDAY 7/24/70 SUNNY AND WARM	TUESDAY 6/22/71 FAIR	FRIDAY 7/23/71 SUNNY AND WARM	TUESDAY 6/20/72 RAIN, WINDY AND COLD	FRIDAY 7/21/72 VERY HOT AND HUMID
(1) Roanoke - Cargill	6851	6738	6516	7108	11657	8856
(2) Cargill - Northwestern	8824	8967	(no count)	8369	13264	10132
(3) Minn. Fed. - Dain Tower	3826	3702	4034	3777	8346	6105
(4) Dain Tower - F&M	(no count)	1520	1161	1125	2490	1939
(5) Lasalle Court	4397	(no count)	5318	5783	6841	6159

TABLE 50

MINNEAPOLIS SKYWAY DAILY SUMMER PEDESTRIAN COUNTS

Source: 1972 Summer Pedestrian Count Report

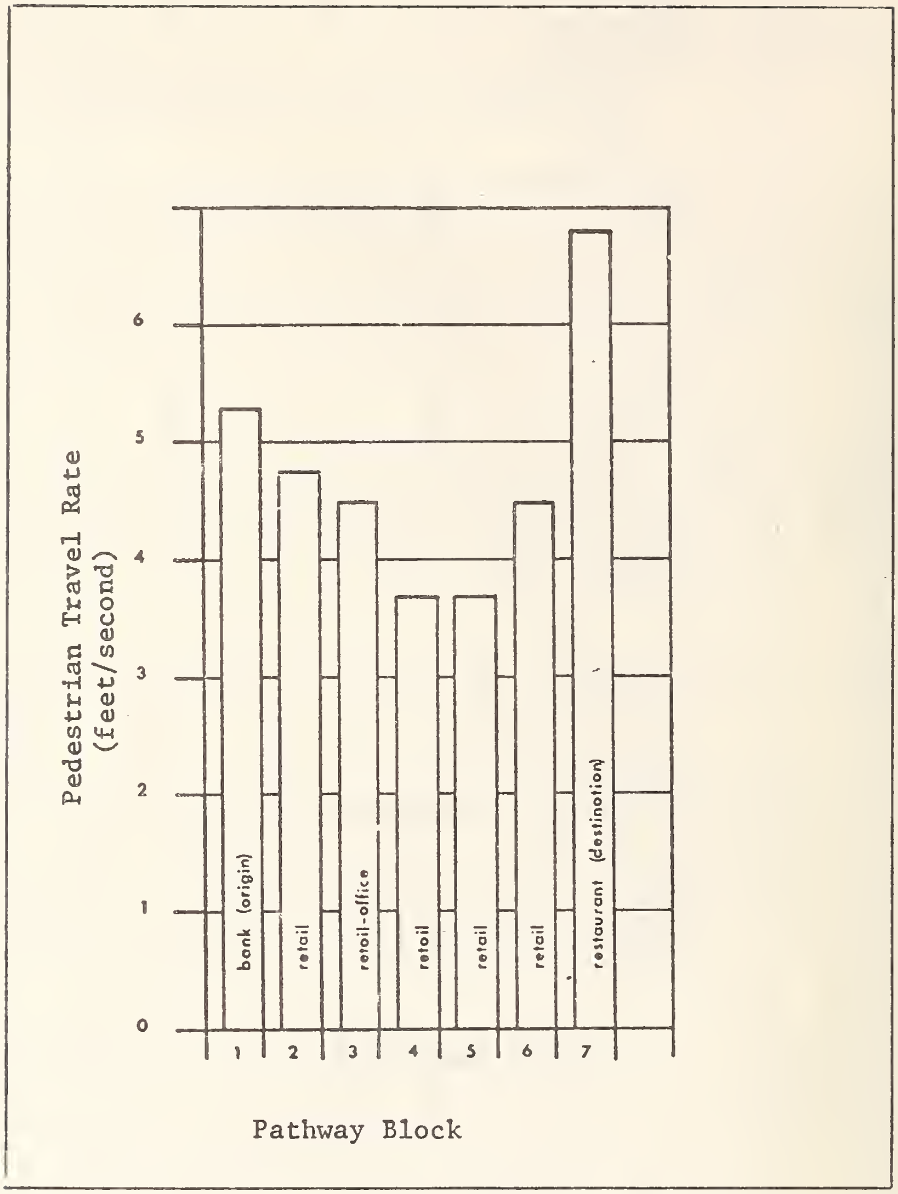

FIGURE 48

TYPICAL VARIATION IN PEDESTRIAN TRAVEL RATE AS A FUNCTION OF ABUTTING PATHWAY LAND USE ACTIVITY

Source: Reference (27), Hoel, Figure V, page 13.

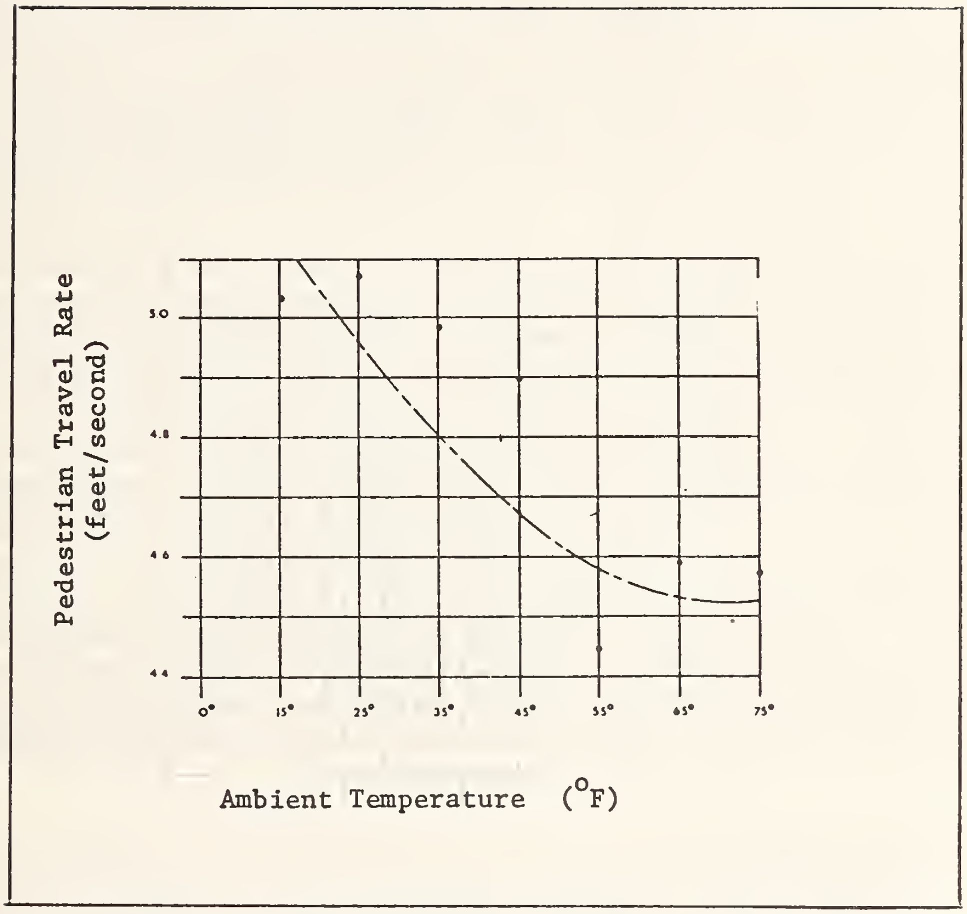

FIGURE 49

PEDESTRIAN TRAVEL RATE VS.
AMBIENT TEMPERATURE

Source: Reference (27), Hoel, Figure IV, page 12.

The lower travel rates are associated with the activity of retail shoppers, but the low temperatures tend to reverse this condition by increasing the rate. Hence, exposure to the elements is not only discouraging the overall level of shopping activity, but is also increasing travel rates and acting to reduce the effect of impulse buying on the part of window shoppers. If instead, the weather is forcing shoppers into the stores, this effect may be reduced, but there is no indication that this is the case.

To note briefly, two other advantages of environmental protection, Smeed has developed a conservative estimate of the risk of accident on a rainy day to be approximately three times greater than on a dry day, and on a rainy night to be about nine times higher than on a dry day.(28) Hence, the extremely high utilization of protected pathways on rainy days could have an effect on the extent to which safety benefits are realized. It should be noted, however, that in the absence of alternative protected pathways the overall level of pedestrian activity would probably be reduced anyway during rainy weather; this would tend to cancel any safety benefits that might result from diverting pedestrian movement away from the vehicular traffic. Finally, Orski has noted numerous instances where the creation of car-free zones has resulted in the stimulation of retail activity with some increases in business up to 35 to 50%.(29) While the provision of separation does not, in fact, create a car-free zone, many of the characteristics are the same. Given that other aspects of the pedestrian system are working effectively, the provision of an enclosed climate-controlled system provides the shopper with an environment downtown much like that found in the viable suburban shopping centers. If the observations noted by Orski are generally applicable, this noise-free, pollution-free, anxiety-free environment could have a positive impact on the abutting retail business.

5.3.3 Coherence

Coherence as a pathway attribute relates to the spatial and directional orientation of the pedestrian as he moves from point to point. Within the context of pedestrian-related impacts or benefits, a coherent system, characterized by visual contact with known points of reference, well conceived signing, and other orientation aids, can relieve the pedestrian of the discomfort and anxiety of being lost and the inconvenient delays of confusion and wasted effort.

Traditionally, pedestrian movement has utilized the parallel grid of sidewalks and paths that border and intersect streets and roadways. From his viewpoint on the sidewalk, the pedestrian can easily discern surrounding buildings and other land uses. The cityscape is clearly visible, and identification of the street with known landmarks assure him that he is proceeding in the right direction within a well-defined and organized network. Notwithstanding the harassment of vehicles, this familiarity with the traditional pathway system allows him the opportunity to increase his perception of the urban space around him. However, when transferred into a totally pedestrian domain such as an extensive below-grade walkway system, much of his orientation is lost. Within the facility, the familiar grid pattern may be modified to achieve more efficient linkages between activity centers. His visual contact with well-known landmarks of the cityscape may be severely reduced. In some cases, the pedestrian may become confused about his right to use certain areas. In effect, the potential may exist for anxiety, disorientation, and confusion with the pedestrian forsaking the benefits of the facility for the familiarity of the sidewalk.

In most cases, orientation and coherence are not a problem. Commuters, for example, quickly learn to negotiate complex pathway systems — witness the underground subway complexes in midtown Manhattan. Shoppers, too, learn to associate with the location of major stores and experience little trouble after several trips. On the other hand, large numbers of people were observed studying graphic layouts within the large Montreal pedestrian system; it was a rainy day, utilization was extremely high, and possibly many of those looking to the layouts for orientation were unfamiliar with the system having come inside because of the weather. This raises the key point regarding orientation — if any attempt is made to provide a coherent system, it should be thorough. It could be argued that inadequate signing, because of the potential for confusing and misleading, and thus discouraging users, may actually be worse than none at all.

A uniform design identity in terms of function and visual quality should be provided throughout the facility pathway network. To minimize his delay and frustration, the pedestrian should be provided with:(30)

- information,
- direction,
- assurance, and
- confirmation.

Considering the pedestrian trip from origin to destination, at the origin he should be provided with information which orients him within the pathway system. This is often accomplished using a familiar "YOU ARE HERE" type of graphic layout. Using a uniform set of terms and graphics, the location of escalation and other points of vertical access and egress should be identified, as should exits to mode exchange terminals and to the street, the location of public conveniences and telephones, and streets, buildings and well-known landmarks close to the facility. Direction should be provided by clearly defining the pathways to each point in the system (graphics should be aligned so that those points to the left of the viewer are shown on his left in the layout, what is ahead is at the top and so on; several examples have been encountered where this has not been done, and it is confusing). During his trip, assurance should be provided especially on long links so that he is confident that he is still following the selected path. Finally, confirmation should be given that he has, in fact, arrived at the desired destination.

The first consideration in the development of a coherent walkway system lies in the design of system configuration itself. Complexity in the physical layout introduces numerous decisions that increase individual anxiety and decrease the effectiveness of the system.(30) The physical layout should be free of ambiguity. Paths should be as direct as possible and should follow natural pedestrian desire lines. Unnecessary visual complexity should be avoided except as it enhances the surrounding space.

Signing should supplement the inherent orientation provided by the system configuration; it should confirm rather than decipher the physical system.(31) Redundancy is helpful for assuring and confirming, and trail blazes are useful elements of signing for providing direction, assurance and confirmation of a route.(30) Lastly, if the space is inherently incoherent, the need for signing increases thus causing a decrease in sign effectiveness.(31) Hence, it should be understood that signing can offer only a partial solution to the problem of loss of orientation in a confused spatial environment.

5.3.4 Interest

The amount of interest that exists along a pathway can have a direct influence on pedestrian route choice, trip lengths and times. Examples of this influence are numerous. In the extreme, recreation environments such as Disneyland and Disneyworld provide comfortable, safe, lively and varied pathways which induce walking trips many times greater than those that would be endured under less pleasant conditions. In Montreal, two parallel pedestrian pathways connect the central railway station block with another block of retail space known as Place Ville-Marie; one pathway is lined with small, diverse shops and the other is a rather barren, office-lined corridor of little interest. Pedestrian counts indicate that the more interesting pathway receives 6 to 8 times the volume of the less interesting one.(32) Although other factors are involved, it is clear that people are choosing the more exciting environment even though they may not be making shopping trips.

In a study of people's attitudes to downtown environments, photographs of various components such as buildings, people, foliage, overhead wires, street paving, sidewalk paving, amount of sky, and signs were presented to a set of observers to be separated into preference piles. Interviews to determine reasons for choices indicated that ". . . The ideal physical-form pattern consisted of a large amount of building-area coverage, and a correspondingly low amount of sky-area coverage (or open space). Other preferences were: Narrower-than-average streets; Inclined streets; Vertical-building-form configurations; A considerable amount of foliage; and few if any signs."(33) While this seems to be in disagreement with the commonly felt need for more urban open space, it supports the view expressed by Contini that narrow streets closed to traffic become—as a result of their intimate scale and intense and varied frontages—like urban "living rooms", full of people and activity.(34)

The implementation of separate pedestrian systems offer an opportunity to create for the pedestrian environmental interest that is not possible where there is vehicular intrusion. This interest will not only effect additional trips on the pedestrian-dominant pathways but will increase trip lengths and times. In a study of pedestrian movement in the Toronto CBD, it was found that lack of interest along the pathway was an impedance factor affecting pathway choice in much the same way as walking and waiting time.(35) Lovemark has shown that an interesting and undisturbed environment will increase average walking trip length by 30 percent and estimates that with careful consideration of the environment, the pedestrian zone of influence might be increased by 50 percent.(36) This could have a substantial effect on the extent and intensity of retailing, and on the overall distribution of land uses.

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CHAPTER 6. OTHER FACILITY IMPACTS

Utilization of facilities gives rise to a series of secondary impacts, namely:

- on motorists,
- on abutting property occupants, and
- on the community and local government.

Briefly, by eliminating pedestrian/vehicular conflict, the motorist is relieved of delays caused by necessity to stop or slow down for pedestrians. Where heavy pedestrian traffic is eliminated from downtown intersections, a more favorable signal cycle can be introduced to increase vehicular flow; this may in turn discourage pedestrian use of the vehicle domain, thereby further enhancing facility utilization. Another secondary set of benefits are those realized by activities that abut the pedestrian facility, primarily merchants and similar activities in an urban environment. Properly designed facilities can create positive impacts for retail merchants, can increase real estate values for property owners, and will allow increased access for deliveries and emergency services. On a more global scale, communities and municipalities stand to realize benefits in terms of increased taxes, mass transit efficiencies, developmental stimulation, and similar impacts.

6.1 FACILITY IMPACTS ON MOTORIST AND VEHICLES

Although one of the primary objectives of traffic planning is to maintain and increase the vehicular capacity of streets, very little attention has been given to the impact of pedestrians on vehicle flow. (1, 2) The effect, however, would appear to be obvious. Turning vehicles in downtown intersections almost always experience delays caused by crossing pedestrians; the delayed turning vehicles, in turn, create the potential for delay to vehicles that are not turning. Pedestrians crossing through-traffic at uncontrolled crossings often cause drivers to stop or slow down to give way. Several efforts which have addressed these delays are discussed in the following sections.

6.1.1 Signal Controlled Intersections

In a study conducted of six signal-controlled intersections in Richmond, Virginia, (2) Nesselrodt and Yu collected data on vehicle delay and nine possible influencing variables primarily related to vehicular and pedestrian movement. Three of the intersections were junctions between moderate to heavy vehicular volume, one-way main streets and relatively high volume one-way cross streets. The other three were junctions between high volume one-way streets and high volume two-way cross streets. Pedestrian movement was on a "share the green" basis and traffic flows were characterized by high frequencies of turning movements.

Data were collected for a series of 15-minute periods for the variables shown in Table 51. These variables were chosen on the basis of previous research, ability to quantify and intuition.

SYMBOL	DESCRIPTION
Y	Vehicle Seconds of Delay
X_1	Number of Pedestrians Actually Involved in Specific Conflict Situations
X_2	Number of Pedestrian Violations (crossing on red or yellow)
X_3	Number of Sides of the Intersection Legs on which Parking is Permitted
X_4	Total Vehicular Intersection Volume
X_5	Total Pedestrian Intersection Volume
X_6	Percentage of Left-Turning Vehicles
X_7	Percentage of Right-Turning Vehicles
X_8	Maximum Red Interval
X_9	Street Width

TABLE 51

VARIABLES RELATED TO VEHICULAR DELAY BY PEDESTRIANS AT INTERSECTIONS

Source: Reference (2), Nesselrodt and Yu, pg. 29.

Using Y, vehicle seconds of delay, as the dependent variable, and X_1, through X_9, as the independent variables, a multivariate regression analysis was performed on the data collected. Three models were developed as shown in Figure 50.

No representative data were given, hence no feeling for the range or magnitude of the vehicle delay can be obtained, nor can the relative strength of the variables (t-values) be assessed. However, in the stepwise regression approach used to develop the models, X_1 and X_4, the pedestrian conflict involvement and vehicular volume variables, were always the first to enter the regression which is an indication of their relative impact on vehicular delay. The obvious conclusion is that high vehicular volumes coupled with conflicting pedestrian movement do have a major impact on the extent of delay experienced by vehicles at busy urban intersections.

As indicated by the models shown in Figure 50 turning movements are a major contributing factor. A detailed study of the delay to right-turning vehicles as a result of pedestrian flow was made using data collected for several intersections in Washington, D.C.(3) Using time-lapse photographic films, data on pedestrian flows, and on vehicular movement and delay were recorded. Analysis of the data indicated that, in general, two distinct intervals occur during each green phase where pedestrian crossings are restricting and delaying right-turn vehicular movement. For heavy pedestrian flow exceeding 500 pedestrians per crosswalk per hour, the phase begins with a very heavy interval of pedestrian/vehicular conflict characterized by relatively high numbers of stopped vehicles waiting to turn; this is then followed rather abruptly by an interval of much weaker conflict characterized by fewer stopped vehicles and lower vehicle delay resulting from fewer pedestrians in the crosswalk. Figure 51 illustrates the nature of this interaction.

The average delay to the first turning vehicle, as determined by the data collected, corresponding to each level of interaction or conflict is shown in Table 52.

The complex relationship between total vehicle delay and factors such as queue length, vehicle flows and pedestrian volumes was examined using a simulation model approach calibrated to the intersectional data collected. The results obtained are shown in Table 53, which shows the relative delay as a function of vehicles per hour, pedestrian flows, and percent of right-turning vehicles;

MODEL I - REGRESSION EQUATION OBTAINED USING DATA FROM ALL SIX INTERSECTIONS

$$Y_I = -87.10 + 2.48\ X_1 + 0.25\ X_4 - 0.05\ X_5 + 2.67\ X_7$$

(R = 0.941, SE = 37.40)

MODEL II - REGRESSION EQUATION OBTAINED USING DATA FROM THE THREE ONE-WAY/ONE-WAY INTERSECTIONS ONLY

$$Y_{II} = -3715.58 + 2.63\ X_1 - 0.28\ X_4 - 0.19\ X_5 + \\ + 12.70\ X_6 + 90.49\ X_9$$

(R = 0.931, SE = 34.65)

MODEL III - REGRESSION EQUATION OBTAINED USING DATA FROM THE THREE ONE-WAY/TWO-WAY INTERSECTIONS ONLY

$$Y_{III} = -164.65 + 2.19\ X_1 + 0.30\ X_4 + 1.78\ X_6 + 5.46\ X_7$$

(R = 0.961, SE = 37.47)

NOTE: R = multiple correlation coefficient

SE = standard error of estimate

FIGURE 50

ESTIMATING EQUATIONS FOR VEHICLE DELAY AT INTERSECTIONS BY PEDESTRIANS

Source: Reference (2), Nesselrodt and Yu; pp. 32-33.

PEDESTRIAN FLOW (peds/hr)	TIME ELAPSED SINCE START OF PHASE (SECONDS)							
	5	10	15	20	25	30	35	40 Over 40
0 - 200 (light)	WEAK							
201-500 (moderate)	STRONG		WEAK					
Over 500 (heavy)	VERY STRONG					WEAK		

FIGURE 51

RELATIVE LEVELS OF PEDESTRIAN/VEHICULAR CONFLICT FOR RIGHT-TURNING VEHICLES AT INTERSECTIONS

Source: Reference (3), Table 15

LEVEL OF INTERACTION	EXPECTED DELAY TO FIRST VEHICLE	MEAN MAXIMUM DELAY *
Weak	0.9 seconds	7 seconds
Strong	3.3 seconds	10 seconds
Very Strong	7.6 seconds	23 seconds

* Mean maximum delay is the average of the decile group of longest delays recorded.

TABLE 52

EXPECTED DELAYS TO FIRST RIGHT-TURNING VEHICLES VERSUS LEVEL OF PEDESTRIAN/VEHICULAR INTERACTION

Source: Reference (3), Tables 3.12 and 3.13.

the value for 800 vehicles per hour, 10% turning right and no pedestrian flow was set to a value of 1.00.

VEHICLE FLOW (vehicles/hr)	RIGHT TURNS (percent)	RELATIVE DELAY TO VEHICLES			
		LEVELS OF PEDESTRIAN FLOW			
		None	Light	Moderate	Heavy
800	10	1.00	0.91	0.95	1.09
	20	1.03	1.14	1.12	1.53
	30	1.10	1.17	1.15	3.79
1200	10	1.54	1.53	1.59	7.08
	20	1.77	1.75	2.29	8.40
	30	1.85	1.89	6.53	11.62

TABLE 53

RELATIVE VEHICULAR DELAY

Source: Reference (3), derived from Table 5.7

6.1.2 Non-Controlled Crossings

Several researchers in Great Britain have examined the effects of pedestrian crossings on vehicular through-traffic in the absence of signalized control. In a study of the effects of zebra crossings, Wilson and Older(4) measured driver behavior in urban settings as a function of pedestrian movement. The resultant effect of drivers stopping or giving way to pedestrians is shown in Figure 52.

Assuming an average vehicle travel time when no pedestrians impede the traffic flow of 12 seconds, the average delay to vehicles can be determined from Figure 52 by subtracting this value from the travel time given by the fitted curve. Table 54 gives estimates of vehicle delay as a function of number of pedestrians crossing per hour.

Smeed,(5) in an earlier analysis of empirical data, developed a relationship between vehicle delay and pedestrian movement for uncontrolled crossings in urban areas given by:

D = total vehicle delay (in hours)

$$= [(0.000913)(P)(Q)]/V^2$$

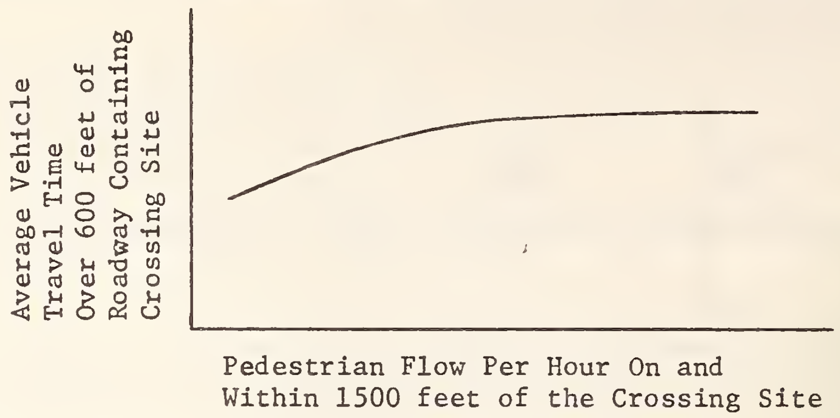

FIGURE 52

VEHICLE TRAVEL TIME VERSUS PEDESTRIAN FLOW

Source: Reference (4), Wilson and Older, Figure 7.

NUMBER OF PEDESTRIAN CROSSINGS PER HOUR	AVERAGE DELAY PER VEHICLE (seconds)	DELAY PER 1000 VEHICLES PER 100 PEDESTRIAN CROSSINGS (seconds)
100	5.7	570
200	7.0	350
300	7.8	260
400	8.3	210
500	8.6	170

TABLE 54

ESTIMATED DELAYS TO THROUGH-FLOW TRAFFIC OVER A DISTANCE OF 600 FEET RESULTING FROM CROSSING PEDESTRIANS

Source: Derived from Figure 52.

where: P = pedestrians crossing per hour

Q = vehicle flow per hour, and

V = traffic speed in miles per hour.

By Smeed's equation, if P = 100 pedestrians per hour, Q = 1,000 vehicles per hour, and V = 20 miles per hour, the delay per 1,000 vehicles per 100 pedestrian crossings is approximately 80 seconds; this value, which is a constant since the total delay is a linear function of P given that Q and V are specified, is substantially lower than the results obtained by Wilson and Older. Some ambiguity regarding the proper value of V (unimpeded, impeded, average could affect the computations obtained using the above equation, and may partially explain the variance in the results.

The above results are useful for the purpose of grossly estimating the impact of pedestrian crossing movement on random free-flow vehicular movement. However, true random flow may be the exception rather than the rule, and other factors such as weather, speed limits and similar variables may act to significantly modify the empirical results presented here.

However, one thing is clear from the results presented in the two preceeding sections and that is—pedestrians impede traffic flow. To the extent that facilities are capable of attracting pedestrians away from points of conflict and interference with vehicles, vehicular movement will be improved.

6.1.3 The Cost of Vehicular Delay

The nature of vehicular travel time and its attendant costs related to vehicle operation and ownership costs, and to the value of driver and passenger time has received a considerable amount of attention.(6) While vehicle-related costs have been isolated and established with a reasonable degree of detail and certainty, per car-hour values for travel time of the driver plus some estimated 1.33 or 1.56 or 1.7 persons per vehicle remains an elusive factor. This not withstanding, it would be of some value to get a gross estimate of the cost of vehicle delay caused by crossing pedestrians for comparison with the cost of pedestrian accidents estimated in Section 5.1.5, and the cost of pedestrian curbside delay estimated in Section 5.2.2.

In Table 54, using results derived from Wilson and Older,(4) an average delay per vehicle of 7.8 seconds over a distance of 600 feet was the estimated effect of 300 pedestrians crossing per hour. This led to an associated total delay per 1,000 vehicles per 100 pedestrian crossings of 260 seconds. Taking this situation as representative, the reduction in miles per hour is given by: (12 seconds is the unimpeded travel time)

$$V = \text{reduction in miles per hour}$$

$$= \left(\frac{600 \text{ feet}}{12 \text{ sec}} \cdot \frac{3600 \text{ sec}}{\text{hour}} \cdot \frac{\text{miles}}{5280 \text{ feet}}\right) - \left(\frac{600}{19.8 \text{ sec}} \cdot \frac{3600}{5280}\right)$$

$$= 34 \text{ mph} - 21 \text{ mph}$$

$$= 13 \text{ mph.}$$

This means that a volume of 300 pedestrians per hour crossing the roadway required an average vehicle to reduce its speed from about 35 mph to 20 mph and consequently, accelerate to 35 mph again. In Table A-8, Wilson and Older(4), gives the excess cost of this speed change cycle above that of continuing at the initial speed of 35 mph as:

$6.84 per 1,000 vehicle cycles.

This figure includes fuel, tires, engine oil, maintenance, and depreciation, but does not include state or federal tax on the fuel. However, Table A-28 of reference (4) gives the excess fuel consumption of this speed change above that of continuing at the initial speed of 35 mph as:

5.28 gallons per 1,000 vehicle cycles.

Using an estimate of $0.11 per gallon for taxes results in an added vehicle operation cost of

$0.58 per 1,000 vehicle cycles.

Hence, the vehicle-related operating costs per 1,000 vehicles per 100 pedestrian crossings is estimated to be:

($6.84 + $0.58)/300 = $2.47

For vehicle delay time, Winfrey(6) suggests that reasonable values of passenger car travel time will take on values up to \$4.00 per car-hour, depending on prevailing local conditions; this limit is based partially on the results of Thomas(7) who suggests a value of \$2.82 per person per hour, and of Lisco(8) who puts commuter time at between \$2.50 to 2.70 per person per hour. Multiplying these values by 1.3 to 1.6 persons per car gives estimates in the range of \$3.25 to \$4.51. Using the conservative value of \$3.25 per car-hour the value of travel time resulting from 260 seconds of delay per 1,000 vehicles per 100 pedestrians is estimated to be:

$$(\$3.25) \times \frac{260}{3600} = \$0.23.$$

Hence, the total estimated cost of vehicle delay by pedestrians is:

$$(\$2.47) + (\$0.23) = \$2.70 \text{ per hour per 1,000 vehicles per 100 pedestrian crossings.}$$

The uncertainty associated with this estimate is apt to be high. However, it would appear that vehicle delay costs are indeed higher than either the cost of pedestrian delay or the cost of pedestrian accidents. Of course this is a generalization that could change substantially in a given situation. The 2-1/2 to 1 relationship between the comparative costs could go much higher in urban business districts where the risk of accident is high and vehicle delay is substantially greater. On the other hand, in residential neighborhoods, dart-out pedestrian accidents could result in very high accident costs without substantially increasing overall vehicle delay time.

6.2 IMPACTS ON ABUTTING PROPERTY

6.2.1 Land Use and Private Sector

Measurement of the impact that a pedestrian facility has on abutting property must consider changes over time usually beginning long before the facility is implemented. A baseline set of measures should be developed prior to implementation. For comparison, a second set would be taken after an initial adjustment period when the novelty has worn off. The ability to measure the specific effects attributable to the facility would be desireable to isolate these from the effects of changes in activities in surrounding areas, so that only the appropriate net impacts would be attributed to the facility.

Assuming these measurements can be made, examination of facility impacts on abutting properties would focus in two primary areas:

- Changes in land utilization characteristics; and
- Changes in private sector revenues, expenditures, and operations.

A more detailed breakdown of specific measures within these areas is given in Figure 53.

The impact of stimulated land values and retail sales resulting from increased pedestrian activity is probably the greatest benefit that accrues to grade-separated systems in downtown retail areas and to a lesser extent in retail areas outside of the CBD which are connected by elements such as pedestrian bridges. In the CBD, the effects of increased safety are diminished because the risks are not generally as high as in other areas (Chapter 5), and the pedestrian shopper and office worker are usually not in the accident prone age groups. The impact on convenience to shoppers (unless they are carrying packages) is usually not significant. Comfort, however, while important because it stimulates utilization, gives rise to the series of impacts on property value and retail sales that dominate all other impacts.

Unfortunately, objective evaluation data are scarce, and the complex interrelationships between cause and effect are almost impossible to separate. Most of the research has focused on street closings and malls; very little is known about these impacts as they relate to grade-separated systems except for subjective assertions of success. The research that has been published tends to support the hypothesis that creation of good pedestrian environments yields positive benefits for abutting property owners and retail occupants. Gantvoort, summarizing research performed primarily in Europe, notes that rents and land values in downtown areas are almost directly related to the volumes of pedestrian traffic on the adjacent sidewalk.(9) He also notes that in several instances, increased pedestrian volumes resulting from bans on vehicular traffic have stimulated retail sales. This trend between the creation of pedestrian systems and stimulated retail sales has been noted in several other sources. In a study performed in Evansville, Indiana, a survey of merchants indicated that they attribute an immediate 40% increase in the quarterly sales of general merchandise to a five block pedestrian mall (called a walkway

To Determine the Impact on:	Measure Changes In:
Land Utilization Characteristics	. Property Tax Assessments . Property Rentals . Property Resale Values . Occupancy/Vacancy Rates . Quality of Abutting Spaces . Extent of Marginal Businesses . Diversity of Land Use Activity . Extent of Municipal Servicing and Control . Impedance (Time, Distance) Between Major Generators . Density of Adjacent Land Use . Extent and/or Cost of Primary Support and Ancillary Services (i.e., Parking)
Private Sector Revenues, Expenditures, and Operations	. Retail Space Rentals (Cost, Area) . Merchant Attitudes . Shopper and Surrounding Office Worker Attitudes . Clientele Profiles, Shopping Habits . Gross Rentail Sales . Average Shopper Expenditure . Reinvestment of Retail-Related Capital into Permanent Inprovement, or Operation . Retail Operating Hours . Volume and/or Quality of Inventory . Extent of Advertizing and Promotion . Property Ownership Patterns . Extent of Effective Trade Area . Level of Merchant Association Activity

FIGURE 53

MEASURE OF FACILITY IMPACT UPON ABUTTING PROPERTY AND ITS OCCUPANTS in the study); the annual increase was estimated to be about 4.7%.(10) The same study, by way of comparison, quotes increases ranging up to 40% for malls in other American cities. Similar positive effects on retail sales have been noted by Orski for traffic bans in cities ranging from Vienna (25-50% increase in first week), to Essen (15-35% increase depending on type of shop), to Tokyo (74% of the merchants favor the ban).(11) In Minneapolis, rents at the second level, in many cases, are equal to those paid by retailers at the street level,(12) and in Montreal, shops abutting the pedestrian system have space rentals equal to, and in some cases, far exceeding those paid by merchants along that cities' main retail street several blocks away where the main department stores are located.(13)

Several caveats are necessary when interpreting those conclusions. First, there is a tendency to accentuate the successful projects while ignoring those where pedestrian facilities have been unsuccessful for one reason or another. The success of a pedestrian system or facility is dependent on a complex set of factors all of which have to be addressed satisfactorily. The simple implementation of an elevated walkway has no inherent attraction to people, nor is closing a street and setting out a few potted plants apt to relieve urban economic decline. Secondly, creation of a system which simply transfers retail activity from one location to another does not result in a net benefit to retailers. The facility would have to stabilize a decreasing trend in property values and retail sales to represent a positive benefit. It is important to realize that a few indicators of success are not necessarily sufficient without a careful examination of the entire system of cause and effect.

6.2.2 Servicing Considerations

A second major impact of pedestrian systems of abutting property relates to servicing properties and distribution of goods. The implementation of a grade-separated facility provides the opportunity to develop an improved system of access to retailing and other establishments for purposes of meeting their servicing and distribution requirements. Indeed, in some cases such as malls, the consideration of servicing requirements is essential. Unless adequate solutions are found, negative impacts on abutting properties will result from the facility. On the other hand, substantial benefits may be realized. In Montreal, for example, servicing concepts were treated as a system equally as important as any other, and a complete horizontally and vertically separated trucking and delivery arrangement was designed. Extensive treatments such as this may not be possible in most cases due to limits on the extent of development involved in the facility project. One alternative which can be considered is the removal of links in the street system which then can be used for servicing shops; not only will this improve servicing, but it will also encourage facility utilization.

6.3 HIGHER ORDER BENEFITS

In the overall impact structure, pedestrian facilities--depending on extent--have the potential to effect higher order benefits such as those shown previously in Figure 53. While many of these benefits can be expressed in numerical terms, only a few can be evaluated monetarily. When dollars can be assigned, the problem remains of isolating those dollars attributable to the pedestrian system from those resulting from closely-related but separate development. There are also problems related to transfer of benefits, sphere of influence, net effects and similar difficulties discussed briefly in the previous section.

In addition, benefits such as increased employment result mainly from the synergism of other effects some of which can be considered to be a result of the walkways while others are not.

The realization of many of the benefits shown in Figure 53 may give rise to an offsetting cost. For example, increased pedestrian activity may result in an increase in the requirements for municipal services such as policing or fire protection. Hence, the increase in tax revenues accruing to the city may be reduced by the need for added services, so that the net effect on total benefit is minimal. Most of these considerations are conjectural, however, since most municipal cost accounts are not designed for this low level of cost analysis. Hence, Figure 54 is provided mainly for completeness of the benefit structure.

FINANCIAL

- Net Increased Tax Revenue From Existing Sources
- Stabilitation of a Declining Tax Base
- Net Additions to the Tax Base

ENVIRONMENTAL

- Improved Air Quality
- Reduced (or Relocation of) Noise
- Increased and Improved Open Space

PERCEPTUAL

- Enhanced Civic Image
- Improved Visual Attractiveness
- Increased Public Optimism and Enthusiasm

SOCIAL

- Less Littering
- Connectivity of Neighborhoods and Other Land Uses
- Less Crime and Vandalism
- Enhanced "Place-to-Be" Image
- Increased Hours of Activity
- More Public Events
- Attraction of Outside Conventions, Expositions

FIGURE 54

POTENTIAL HIGHER ORDER FACILITY BENEFITS

CHAPTER 6 REFERENCES

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(11) C. K. Orski, "Car-Free Zones and Traffic Restraints: Tools of Environmental Management," *Highway Research Record No. 406*, 1972.

(12) Interview with O. Harold Swanson of FDS Properties, Inc; July 25, 1973.

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CHAPTER 7. COSTS AND BENEFITS OF PEDESTRIAN HIGHWAY CROSSINGS

7.1 COST FACTORS

Specific cost factors for highway overpasses and underpasses are given in Section 3.2.3. A comparative analysis of highway crossings based solely on costs is given in Section 3.3.7.

Examination of numerous studies which utilize cost estimates of highway crossing structures has indicated that several elements are overlooked or disregarded.(1) This is especially true when area-wide average figures are used to estimate the cost of a proposed structure; unless the proposed facility is "average," estimated costs are apt to be significantly different than actual costs, and the study results may be inaccurate. The areas most often overlooked are:

- annual costs of maintenance,
- vehicle delay costs during facility construction,
- terminal (ramps, stairs) right-of-way costs, and
- effects of span lengths and total facility length.

7.2 BENEFIT FACTORS

A list of the benefits that result from providing grade-separated pedestrian crossings over streets and highways is given in Table 55; each of these elements is discussed in more detail in the sections that follow.

Before discussing each of the benefits in Table 55 in more detail, several general concepts related to the realization of benefits will be discussed. First, many benefits including those associated with vehicle delay time and operation, and with the cost of pedestrian accidents depend on facility utilization. When pedestrians have access to the roadway, they are in effect provided with a choice of using the surface route or crossing via the separation facility. If they choose to cross at grade, many of the benefits of the facility are lost; in some cases, such as pedestrian accidents, the facility may actually produce a negative effect since vehicles may not expect to encounter pedestrians crossing the roadway in the vicinity of a grade-separated crossing. The cost of providing fencing or other barriers should be included as part of capital costs of providing the crossing structure,

REDUCED COST OF VEHICULAR DELAY TIME
REDUCED COST OF VEHICULAR OPERATION
REDUCED COST OF PEDESTRIAN INJURY AND FATALITY
REDUCED COST OF VEHICULAR ACCIDENTS OF PEDESTRIAN CAUSATION
REDUCED COST OF ALTERNATIVE CROSSING CONTROLS
REDUCED COST OF PEDESTRIAN ROADSIDE DELAY
REDUCED COST OF ALTERNATIVE TRANSPORTATION MODES
REDUCED COST OF PEDESTRIAN TRIP TIME
IMPROVED LINKAGE OF NEIGHBORHOODS AND OTHER LAND USES

TABLE 55
BENEFITS OF GRADE-SEPARATED PEDESTRIAN CROSSINGS

so that benefits can be computed under the assumption of 100% utilization. Alternatively, the effect of reduced benefit resulting from reduced utilization might be compared to the added cost of restricting pedestrian crossing access.

The second general concept deals with the realization of benefits given that no pedestrian access across the highway was allowed in the first place. When considering the benefits of a grade-separated pedestrian crossing structure across a totally controlled-access highway, no consideration can be taken for the benefits of improved vehicle movement since these factors did not originally depend on the existence of the crossing. Nor can full benefit be taken for reduced pedestrian accidents (although this may be a valid consideration if experience shows that pedestrians are gaining access to the roadway for the purpose of crossing), reduced vehicle accidents or pedestrian crossing delays. At best the only benefits realized are those that relate to provision of alternative transportation, pedestrian convenience such as reductions in trip time, and improved linkage.

7.2.1 Reduced Cost of Vehicular Delay Time

In Section 6.1.3, a gross estimate of the cost of vehicular delay time due to crossing pedestrians was computed to be about $0.23 per 1000 vehicles per hour per 100 pedestrians crossing per hour. This figure was derived for the purpose of comparison with other gross measures of the costs of pedestrian accidents and delay. In general, and certainly in actual practice, this figure is not applicable.

Instead, the cost of vehicular delay should be estimated to suit conditions that exist at the proposed or actual facility site. The computation will take the general form shown in Figure 55.

$$B_1 = \text{ANNUAL BENEFIT OF REDUCED VEHICULAR DELAY TIME}$$

$$= \begin{bmatrix}\text{NUMBER OF}\\ \text{VEHICLES}\\ \text{DELAYED PER}\\ \text{UNIT TIME}\end{bmatrix} \text{x} \begin{bmatrix}\text{AVERAGE}\\ \text{SECONDS}\\ \text{DELAY PER}\\ \text{VEHICLE}\end{bmatrix} \text{x} \begin{bmatrix}\text{NUMBER OF}\\ \text{TIME UNITS}\\ \text{PER YEAR}\end{bmatrix}$$

$$\text{x} \begin{bmatrix}\text{VEHICLE TIME}\\ \text{COST PER HOUR}\end{bmatrix} \text{x} \begin{bmatrix}\text{HOURS TO SECONDS}\\ \text{CONVERSION 1/3600}\end{bmatrix}$$

FIGURE 55

COMPUTATION OF VEHICLE DELAY TIME SAVING BENEFIT

The first two factors in the above computation, the number of delayed vehicles and average delay per vehicle, can be simply determined using appropriate sampling techniques at the proposed or actual crossing point prior to construction of the facility. An alternative means of computing the number of vehicles delayed would be to multiply total volume per unit time times the percent of all vehicles delayed. The third factor, the number of time units (day, hours, etc.) will depend on local conditions. If vehicle delays result from school crossings, then the appropriate choice of time units would coincide with the period (school days per year, and hours per day of use, for example) over which these crossings were causing delays. The cost of vehicle time per hour was discussed in Section 6.1.3 where it was noted that values in the range of \$3.25 to \$4.15 per vehicle per hour are appropriate for commuter time. This value would also be chosen to suit local conditions. Examples of computations of vehicle delay are given in Section 7.3.1 and 7.3.2.

The benefit associated with elimination of vehicle delay is affected by both utilization and access control as noted in Section 6.1. If the facility is not utilized by all crossing pedestrians, then the full extent of this benefit will not be realized. In this case, the net benefit can be estimated from the total potential benefit by assuming that it is a linear function of utilization and making the simplified computation shown in Figure 56.

B_1' = NET VEHICLE DELAY BENEFIT

$= U \cdot B_1$

where: B_1 is computed as shown in Figure 72, and

U = percentage of pedestrians using the grade-separated facility.

FIGURE 56

COMPUTATION OF NET VEHICLE DELAY BENEFIT BASED ON FACILITY UTILIZATION

Also, if the crossing site is across a full-access controlled highway, no vehicle delay benefit will accrue to the facility.

7.2.2 Reduced Cost of Vehicular Operation

In addition to reducing the effects of vehicular delays caused by the need to stop or slow down for pedestrians, grade separation may also provide the benefit of reducing the cost of vehicle operation associated with these changes. Each time the vehicle decelerates and subsequently accelerates back to normal operating speed, with possible idling if it is required to come to a full stop, it incurs an increase in operating cost over that required to maintain it at normal speed. When grade-separated facilities succeed in eliminating pedestrians from the vehicle path, then the attendant savings in operating cost can be considered as a benefit of the facility.

The computation of the benefit that results from reduced vehicle operating costs is shown in Figure 57. The first factor is equivalent to the number of vehicles delayed used to compute B_1 in Figure 55. The third factor, increased vehicle operating cost per vehicle-cycle, refers to the net increase in operating cost each time a vehicle goes through the stopping or slowing down cycle. This cost depends on vehicle type, roadway conditions, initial operating speed, extent of speed reduction, length of idling time (if applicable), and the unit costs of fuel, tires, engine oil, maintenance, depreciation, and taxes. The computation of the third factor in the equation for B_2 is beyond the scope of this report. However, this information has been tabulated for easy use in several available sources. An AASHO report$^{(2)}$ provides a traditional source of these data, but since it dates back to 1960 some care will be required to convert its contents to

$$\begin{aligned} B_2 &= \text{ANNUAL BENEFIT OF REDUCED VEHICLE OPERATION COST} \\ &= \begin{bmatrix}\text{NUMBER OF VEHICLES}\\ \text{DELAYED PER UNIT TIME}\end{bmatrix} \times \begin{bmatrix}\text{NUMBER OF TIME}\\ \text{UNITS PER YEAR}\end{bmatrix} \\ &\quad \times \begin{bmatrix}\text{INCREASED VEHICLE}\\ \text{OPERATING COST PER}\\ \text{VEHICLE-CYCLE}\end{bmatrix} \end{aligned}$$

FIGURE 57

COMPUTATION OF VEHICLE OPERATION
COST SAVING BENEFIT

present-day dollars. A recent reference work by Winfrey(3) provides a more up-to-date and comprehensive source on the same subject. These references should be consulted when computing the cost of vehicle operation. Representative computations, following the format shown in Figure 57 are given in Sections 7.3.1 and 7.3.2.

In a manner similar to that described in Section 7.2.1 for vehicle delays, the net benefits associated with reducing vehicle operating costs depend on facility utilization, with full benefit being realized only if 100% utilization is achieved. Otherwise, an adjustment such as that shown in Figure 56 should be made. Also, no vehicle operation benefits accrue to pedestrian facilities over full-access controlled highways.

7.2.3 Reduced Cost of Pedestrian Injury and Fatality

The cost of pedestrian injury and fatality was discussed in a general way in Section 5.1. In actual practice, the derivation of benefits that will result from implementation of a pedestrian facility will depend on conditions prevailing at the proposed or actual facility site. In general, the reduced dollar cost of accidents can be computed as shown in Figure 58.

$$
\begin{aligned}
B_3 &= \begin{array}{l}\text{ANNUAL BENEFIT OF REDUCING PEDESTRIAN}\\ \text{INJURIES AND FATALITIES}\end{array}\\
&= \left\{ \left[\begin{array}{l}\text{EXPECTED REDUCTION}\\ \text{IN THE NUMBER OF PED.}\\ \text{INJURIES PER YEAR}\end{array}\right] \times \left[\begin{array}{l}\text{COST PER}\\ \text{PEDESTRIAN}\\ \text{INJURY}\end{array}\right] \right\}\\
&\quad + \left\{ \left[\begin{array}{l}\text{EXPECTED REDUCTION}\\ \text{IN THE NUMBER OF PED.}\\ \text{FATALITIES PER YEAR}\end{array}\right] \times \left[\begin{array}{l}\text{COST PER}\\ \text{PEDESTRIAN}\\ \text{FATALITY}\end{array}\right] \right\}
\end{aligned}
$$

FIGURE 58

COMPUTATION OF PEDESTRIAN ACCIDENT COST SAVING

The problem remains one of estimating the expected accident reduction factors. If the reason for considering a pedestrian facility is in response to an accident warrant, then it is probable that a review of accident records may result in a statistical basis for projecting the potential for future accidents. In most instances, a prior period of five or more years is examined, and the accident experience in this period used to predict the expected number of accidents in the future. For simplifications, the projection will often be assumed constant without influence of future increases in either pedestrian or vehicular volumes; this tends to be a conservative approach since increases in these volumes would tend to increase the number of accidents per year.

In the examples presented in Section 7.3.2, the number of accidents in a prior period were known, without discrimination by fatality or injury. However, the city-wide ratio of fatalities to accidents was known. These statistics could be used to compute the number of fatalities and injuries per year by using the conversion formula given in Figure 59.

$$\begin{bmatrix}\text{FATALITIES}\\ \text{PER YEAR}\end{bmatrix} = \frac{1}{N}\begin{bmatrix}\text{NUMBER OF}\\ \text{ACCIDENTS IN}\\ \text{PRIOR N YEARS}\end{bmatrix} \times \begin{bmatrix}\text{FATALITIES}\\ \text{PER}\\ \text{ACCIDENT}\end{bmatrix}$$

$$\begin{bmatrix}\text{INJURIES}\\ \text{PER YEAR}\end{bmatrix} = \frac{1}{N}\begin{bmatrix}\text{NUMBER OF}\\ \text{ACCIDENTS IN}\\ \text{PRIOR N YEARS}\end{bmatrix} \times \left[1.0 - \begin{pmatrix}\text{FATALITIES}\\ \text{PER}\\ \text{ACCIDENT}\end{pmatrix}\right]$$

FIGURE 59

COMPUTATION OF FATALITIES AND INJURIES USING FATALITIES PER ACCIDENT

The other factors in the pedestrian accident benefit computation shown in Figure 58 are the cost per pedestrian injury and cost per pedestrian fatality. The costs of pedestrian accidents, developed in Section 5.1.5, are summarized in Table 56.

COST OF PEDESTRIAN FATALITY	$200,700
COST OF PEDESTRIAN INJURY	$ 11,600
WEIGHTED AVERAGE ACCIDENT Costs (see note)	
- urban	21,400
- rural	36,600
- all	24,100

NOTE: Weightings based on 1971 national statistics of injuries and fatalities.

TABLE 56
PEDESTRIAN ACCIDENT COSTS

A further breakout of the cost of pedestrian fatalities is useful due to the frequent consideration of pedestrian crossing facilities in the vicinity of schools. The largest cost component in the $200,700 cost per fatality figure is due to $132,000 in wage losses. This figure is obtained as the weighted average of approximate wage losses for children (0 to 20 years of age) of $151,000, and for adults (aged 20 years and over) of $125,000.(4) Making the proper adjustments in the total fatality cost yields the figures shown in Table 57. Limited information on severity precludes a similar refinement of pedestrian injury costs.

As in the preceding sections, facility utilization and highway access limitations will influence the extent to which benefits will realized. In the case of full-access-controlled highways, a benefit for reduction in the cost of pedestrian fatality and injury can only be given to the extent that experience shows that pedestrians are gaining access to the roadway for the purpose of crossing. It should also be noted that when dealing with facility utilization, it may be in order to apply different factors for children and adults; a Los Angeles study reported by the Institute of Traffic Engineers indicated that utilization by school children of an existing overpass was 24% while utilization by other pedestrians (presumably adults and teenagers) was only 2%; other crossings were made at an adjacent signalized crosswalk or

	COST PER FATALITY
Child - 0 to 20 years	$220,700
Adult - 20 years and over	$194,700
Average - all ages	$200,700

TABLE 57

COST PER PEDESTRIAN FATALITY BY AGE GROUP

Source: Reference (4), US DOT/NHTSA, pg. E-13.

between the overpass and the crosswalk.(1) While the utilization rates are low, they do indicate that substantial differences may exist with regard to different groups. Assuming that accident rates before and after construction of a grade-separated facility are proportional to the rate of facility utilization, an expanded computation, similar to that shown in Figure 58 could be made as shown in Figure 60.

7.2.4 Reduced Cost of Vehicular Accidents of Pedestrian Causation

A component for property damage is included in the total cost of pedestrian injuries and fatalities for accidents with pedestrian involvement. Another possible benefit of separating pedestrian and vehicle movement is the reduction in cost of vehicle-only accidents caused by pedestrians. Accidents of this type would include a vehicle colliding with a fixed object after swerving to avoid striking a pedestrian who appeared suddenly in the roadway; or rear-end collisions associated with vehicles stopping or slowing down for pedestrians at controlled or uncontrolled crossings. By eliminating pedestrian movement from the roadway, accidents of this characteristic type may be avoided.

Unfortunately, no research exists on this subject. It remains a matter of examining local conditions. If accident records indicate that vehicle involvement in accidents of pedestrian causation can be

$$B_3^* = \text{ALTERNATIVE COMPUTATION FOR ANNUAL BENEFIT OF REDUCING PEDESTRIAN INJURIES AND FATALITIES}$$

$$= (\$220{,}700) \text{ x } \begin{bmatrix}\text{EXPECTED}\\ \text{NUMBER OF}\\ \text{CHILD FATALITIES}\\ \text{PER YEAR}\end{bmatrix} \text{ x } \begin{bmatrix}\text{FACILITY}\\ \text{UTILIZATION}\\ \text{RATE FOR}\\ \text{CHILDREN}\end{bmatrix}$$

$$+ (\$194{,}700) \text{ x } \begin{bmatrix}\text{EXPECTED}\\ \text{NUMBER OF}\\ \text{ADULT FATALITIES}\\ \text{PER YEAR}\end{bmatrix} \text{ x } \begin{bmatrix}\text{FACILITY}\\ \text{UTILIZATION}\\ \text{RATE FOR}\\ \text{ADULTS}\end{bmatrix}$$

$$+ (\$11{,}600) \text{ x } \Bigg[\begin{pmatrix}\text{EXPECTED NUMBER OF}\\ \text{CHILD INJURIES PER}\\ \text{YEAR}\end{pmatrix} \begin{pmatrix}\text{FACILITY}\\ \text{UTILIZATION}\\ \text{RATE FOR}\\ \text{CHILDREN}\end{pmatrix}$$

$$+ \begin{pmatrix}\text{EXPECTED NUMBER}\\ \text{OF ADULT INJURIES}\\ \text{PER YEAR}\end{pmatrix} \begin{pmatrix}\text{FACILITY}\\ \text{UTILIZATION}\\ \text{RATE FOR}\\ \text{ADULTS}\end{pmatrix} \Bigg]$$

FIGURE 60

ALTERNATIVE COMPUTATION OF PEDESTRIAN ACCIDENT COST SAVING predicted based on past experience, an estimate of this effect should be projected and a cost assigned. It is probable that most accidents of this type will involve property damage only; based on an estimate made using state highway accident cost studies,(4) the property damage cost per involvement is about $300.00.

7.2.5 Reduced Cost of Alternative Crossing Controls

The construction of a grade-separated pedestrian crossing may result in the elimination of other crossing controls such as signalization, or near schools, crossing guards. The reduced costs of these controls can be considered as a benefit of the crossing facility. In the case of signalization, the reduced cost should take into consideration the shorter service life of the signals when compared to a facility; renewal will probably have to be considered to obtain comparable results. For school crossing guards, only the net reduction in future cost can be attributed to the facility in cases where provision of some supervision continues to be an expense.

An example of a comparison between the economic cost of overcrossings, signals and crossing guards is given in Section 7.3.3.

7.2.6 Reduced Cost of Pedestrian Roadside Delay

Separated crossing facilities can potentially reduce pedestrian trip times, thereby effecting a pedestrian cost benefit. In one sense, the facility can reduce trip distance as in the case of a crossing at a full-access controlled highway; trip distance may also be lengthened as in the situation where barriers are introduced to force facility utilization where no previous restriction to crossing movement existed (vehicles notwithstanding). In the second sense, a facility may provide some improvement in the time to cross at the point of crossing; that is, it will relieve the roadside delay of pedestrians due to vehicles. This time saving can be considered as a benefit of the facility.

In practice, the extent of benefit attributable to reduction in roadside delay will depend on four factors:

- average number of pedestrians crossing per unit time;
- average at-grade crossing time (including delay);

- estimated crossing time via facility; and
- value of pedestrian time.

The first two factors can be obtained from sampled observations at the proposed or actual site. In determining the average at-grade crossing time, the actual walking time should be added to the average delay due to signalization or waiting for adequate gaps in traffic. Estimates of the crossing time via the facility should consider the extra time required to effect a change in grade via stairs, ramps or similar means. In both cases, the point to point distances should be equal or appropriate adjustments made to ensure comparable results.

The value of pedestrian time requires some careful consideration. When the pedestrians are children, the value placed on their time has to be small, possibly zero. A similar situation exists for shoppers, although some positive value of time is in order. However, if the pedestrian is a commuter or is on a business trip, a value similar to the figure of \$2.40 per hour given in Section 5.2.3 should be used. The primary point is that in general, unless numerous pedestrians using the facility are on work-related trips, the benefit that accrues by reducing roadside delay is minimal, and the computation should be bypassed.

The computation of benefits related to reduced roadside delay is shown in Figure 61.

Note that it is possible that the facility will actually result in an increased delay to crossing pedestrians rather than a reduction if the time to cross via the facility exceeds the time to cross at-grade. In this case, the value for B_6 will be negative and will represent a cost attributable to the facility rather than a benefit.

It should be understood that this particular benefit has no meaning with regard to facilities crossing full-access controlled highways since, except in unusual circumstances, no pedestrians were crossing at these sites, and hence, the concept of additional delay is meaningless. Instead a reduction in pedestrian overall trip time as discussed in Section 7.2.8 should be considered.

7.2.7 Reduced Cost of Alternative Transportation Modes

In the case of full-access controlled highways, pedestrian facilities can substantially reduce the costs associated with the

$$B_6 = \begin{array}{l}\text{ANNUAL BENEFIT OF REDUCING PEDESTRIAN}\\ \text{ROADSIDE CROSSING DELAY}\end{array}$$

$$= \begin{bmatrix}\text{AVERAGE}\\ \text{NUMBER OF}\\ \text{PEDESTRIANS}\\ \text{CROSSING PER}\\ \text{UNIT TIME}\end{bmatrix} \times \begin{bmatrix}\text{TIME}\\ \text{UNITS PER}\\ \text{YEAR}\end{bmatrix} \times \begin{bmatrix}\text{VALUE OF}\\ \text{PEDESTRIAN}\\ \text{TIME PER}\\ \text{HOUR}\end{bmatrix}$$

$$\times \begin{bmatrix}\text{HOURS TO}\\ \text{SECONDS}\\ \text{CONVERSION}\\ 1/3600\end{bmatrix} \times \left[\begin{pmatrix}\text{TIME TO CROSS}\\ \text{AT-GRADE (in-}\\ \text{cluding}\\ \text{delays)}\\ \text{(seconds)}\end{pmatrix} - \begin{pmatrix}\text{TIME TO}\\ \text{CROSS VIA}\\ \text{FACILITY}\\ \text{(seconds)}\end{pmatrix}\right]$$

where:

$$B_6 = \begin{cases}\text{Benefit} & \text{if } B_6 > 0\\ \text{Cost} & \text{if } B_6 < 0\end{cases}$$

FIGURE 61

COMPUTATION OF PEDESTRIAN ROADSIDE DELAY COST SAVING

necessity to use alternative means of transportation to reach destinations separated by the highway. In the simplest case, where an access-controlled highway bisects a school district, it may be necessary to provide busing to transport children from residences on one side of the highway to a school on the other side. However, the construction of a highway crossing may allow walking trips to school, and elimination of the busing at a substantial cost saving; this saving would be a benefit attributable to the facility. Although not as easily measured, other types of trips such as trips to shopping centers by car could potentially be converted into walking trips by construction of a grade-separated facility over an access-controlled highway. In concept, this could result not only in an energy savings, but in a possible time saving as well.

An example, using student busing and car pooling alternatives is presented in Section 7.3.4.

7.2.8 Reduced Cost of Pedestrian Trip Time

This measure is similar to the benefit resulting from a reduction in roadside delay discussed in Section 7.2.6. Unlike that factor, however, this one relates primarily to pedestrian movement across full-access controlled highways. When the highway represents a barrier and pedestrian movement is restricted to existing separation (possibly shared with vehicles), the provision of an additional separated crossing will act to reduce pedestrian trip times and distances. The additional crossing tends to reduce the constraining effect of the highway barrier and results in a pedestrian convenience benefit.

The difficulty lies in measuring this effect. It requires an analysis of land use in the area surrounding the proposed or actual site, together with some estimates of pedestrian movements in terms of numbers, trip types, origins and destinations. In some cases, such as school trips where residence and school define the trip ends, this can be easily accomplished; in other situations, however, where movement is not so neatly defined, it would require the application of techniques such as surveys, aerial photography or numerous station counts. The latter are usually prohibitive from the standpoint of expense (which should be considered as part of facility cost). In most cases, cost and benefit analysis will be abandoned in favor of more traditional warrant approaches.

Where data are available at reasonable cost, a computation as shown in Figure 62 would be made in a manner similar to that discussed in Section 7.2.6.

7.2.9 Improved Linkage of Neighborhoods and Other Land Uses

Many highways, especially those which have full access control, can be viewed as barriers that intrude upon local community living patterns.(1) Pedestrian crossing facilities can partially serve to restore pedestrian movement and related social interaction disrupted by the highway. The pecuniary benefits that result from a restoration of linkages are almost impossible to quantify; rather subjective criteria -- such as spacing warrants -- that are reflective of societal desires and demands replace the economic considerations of cost and benefit.

$$B_8 = \begin{array}{l}\text{ANNUAL BENEFIT OF REDUCING PEDESTRIAN}\\ \text{TRIP TIME}\end{array}$$

$$= \begin{bmatrix}\text{ESTIMATED NUMBER}\\ \text{OF TRIPS DIVERTED}\\ \text{TO THE FACILITY}\\ \text{PER UNIT TIME}\end{bmatrix} \times \begin{bmatrix}\text{AVERAGE}\\ \text{TRIP TIME}\\ \text{SAVING}\\ \text{(minutes)}\end{bmatrix} \times \begin{bmatrix}\text{VALUE OF}\\ \text{PEDESTRIAN}\\ \text{TIME PER}\\ \text{HOUR}\end{bmatrix}$$

$$\times \begin{bmatrix}\text{TIME UNITS}\\ \text{PER YEAR}\end{bmatrix} \times \begin{bmatrix}\text{HOURS TO}\\ \text{MINUTES}\\ \text{CONVERSION}\\ 1/60\end{bmatrix}$$

FIGURE 62

COMPUTATION OF PEDESTRIAN TRIP TIME SAVING

Nevertheless, the improved linkage of neighborhoods and other land uses is a positive benefit which should be attributed to pedestrian facilities.

7.3 COMPUTATIONAL EXAMPLES

Following are several examples of cost calculations for specific facilities and discussions of what was or should have been done in each case.

7.3.1 Example No. 1 Involving Pedestrian Accident and Delay Reduction Benefits

A pedestrian overpass across a major expressway is being considered.(5) The capital cost of the overpass will be compared with the benefits resulting from reductions in pedestrian accidents and delays. Substantial benefits associated with reduction in overall pedestrian trip times and with the net effects of increased generation of pedestrian trips are recognized but cannot be quantified due to lack of data. Assumptions and computations associated with facility cost, accident benefit and delay benefit are shown in Figures 63, 64, and 65, respectively. The cost/benefit computation is given in Figure 66.

ASSUMPTIONS:

1. Overpass capital cost (including cost of inflation and unknown contingencies) = $88,000

2. Overpass service life is estimated as 40 years

3. The applicable interest rate is 6%.

COMPUTATION:

The tabulated capital recovery factor (CRF) for 6% and 40 years is 0.0665, hence

C = equivalent uniform annual cost
= (CRF) x (capital cost)
= 0.0665 x $88,000
= $5,850

FIGURE 63

COMPUTATION OF UNIFORM ANNUAL COST FOR EXAMPLE NO. 1 OVERPASS

ASSUMPTIONS:

1. Based on accident experience over the prior 13-year period, pedestrian accidents are projected at 0.36 accidents per year.
2. The associated fatality rate is 10.3 fatalities per 100 pedestrian accidents.
3. The cost per pedestrian fatality is based on the 1964 National Safety Council figure of $34,400.
4. The cost per pedestrian injury used is $640.
5. Approximately 30% of all pedestrians crossing are of secondary school age with a potential average income of $7,000 per year.
6. The present worth of future earnings given in (5) is assumed to be balanced by inflation; and
7. Future earnings given in (5) will extend 40 years.

COMPUTATIONS:

1. Due to the appreciably higher loss associated with the children, assumptions (5), (6) and (7) were used to compute the cost of a child fatality to be:

$$40 \text{ years} \times \frac{\$7000}{\text{year}} = \$280{,}000$$

2. The average cost of a fatality is computed based on the 70% and 30% weights of adults and children to be:

$$[(0.7) \times (\$34{,}400)] + [(0.3) \times (\$280{,}000)]$$

$$= \$24{,}100 + \$84{,}000 = \$108{,}100$$

3. The annual pedestrian accident benefit is given by:

$$\boxed{\begin{array}{lccccccc} B_3 & = & \begin{array}{c}\text{INJURIES}\\ \text{PER}\\ \text{YEAR}\end{array} & \begin{array}{c}\text{COST}\\ \text{PER}\\ \text{INJURY}\end{array} & + & \begin{array}{c}\text{ACCIDENT}\\ \text{PER}\\ \text{YEAR}\end{array} & \begin{array}{c}\text{FACILITIES}\\ \text{PER}\\ \text{ACCIDENT}\end{array} & \begin{array}{c}\text{COST}\\ \text{PER}\\ \text{FATALITY}\end{array} \\ & = & (0.36) & (\$640) & + & (0.36) & (.103) & (\$108{,}100) \\ & = & \$230 & + & \$4000 = & \$4{,}230 & & \end{array}}$$

FIGURE 64

COMPUTATION OF PEDESTRIAN ACCIDENT BENEFIT FOR EXAMPLE NO. 1 OVERPASS

ASSUMPTIONS:

1. Present pedestrian volumes of 134 pedestrians per day will grow at a rate of 2% per annum given an average volume over the 40-year service life of approximately 200 pedestrians per day.

2. Average reduction in pedestrian delay per crossing is one minute; and

3. Pedestrian time is valued at \$2.00 per hour or about 70% of \$2.82 as determined in the Stanford Research Institute study (see Section 6.1.3).

COMPUTATION:

The annual benefit due to reduced pedestrian delay is given by:

$$B_6 = \left(\begin{array}{c}\text{Crossings}\\ \text{per}\\ \text{Day}\end{array}\right)\left(\begin{array}{c}\text{365 Days}\\ \text{per}\\ \text{Year}\end{array}\right)\left(\begin{array}{c}\text{\$2.00 per}\\ \text{Hour Ped.}\\ \text{Time}\end{array}\right)$$

$$\times \left(\begin{array}{c}\text{1 Minute}\\ \text{per}\\ \text{Crossing}\end{array}\right)\left(\frac{1}{60}\ \begin{array}{c}\text{Hours per}\\ \text{Minute}\end{array}\right)$$

$$= (200)\ (365)\ (\$2.00)\ (1)\left(\frac{1}{60}\right)$$

$$= \underline{\underline{\$2{,}430}}$$

FIGURE 65

COMPUTATION OF PEDESTRIAN DELAY TIME BENEFIT FOR EXAMPLE NO. 1 OVERPASS

The benefit to cost computation is:

$$\frac{B}{C} = \frac{B_3 + B_6}{C} = \frac{\$4{,}230 + \$2{,}430}{\$5{,}850}$$

$$= \frac{\$6{,}660}{\$5{,}850} = \underline{\underline{1.14}}$$

FIGURE 66

COMPUTATION OF THE BENEFIT TO COST RATIO FOR EXAMPLE NO. 1 OVERPASS

On the basis of pedestrian accident and delay reduction alone, the benefit over cost difference is marginal; the decision would probably require the consideration of higher level criteria. Further support of the marginal nature of the analysis is evident in the following (note that no issue is taken with the value employed, but only in the subsequent application of these figures):

1. The uniform annual cost of the overpass does not allow for maintenance cost.

2. In the computation of pedestrian accident benefit, the benefit attributed to pedestrian injury reduction should have been computed using

$$\begin{pmatrix}\text{Injuries}\\ \text{per}\\ \text{Year}\end{pmatrix} = \begin{pmatrix}\text{Accidents}\\ \text{per}\\ \text{Year}\end{pmatrix} \cdot \begin{pmatrix} 1.0 - \begin{matrix}\text{Fatalities}\\ \text{per}\\ \text{Accident}\end{matrix}\end{pmatrix}$$

which gives a figure of

(0.36) (0.897) ($640) = $210

instead of $230.

3. In the computation of pedestrian delay benefit it is questionable if full effect of children's time should have been included; instead, using the 70% accruing to adults only would be more realistic. This would give a revised benefit of $1,700.

4. Assuming an annual maintenance cost of $100 and introducing the changes noted above, the revised benefit to cost ratio would be

$$\frac{\$4210 + \$1700}{\$5950} = \frac{5910}{5950} = 1.00$$

7.3.2 Example No. 2 Involving Pedestrian Accident and Vehicular Delay and Operation Benefits

A pedestrian overpass across a four-lane undivided urban street which would link a high school and proposed swimming pool site with some residential areas is considered.(6) At present, appreciable conflicts exist between pedestrians and turning vehicles and transit buses during the hours after school. The capital cost of the overpass will be compared with the benefits resulting from reducing pedestrian accidents and from vehicular delay and operating cost reductions. Secondary and indirect benefits resulting from reductions in rear-end accidents, and improved linkage of neighborhoods especially for young people, are recognized but cannot be quantified. Assumptions and computations related to accident benefit and vehicle delay and operation benefits are shown in Figures 67, 68, and 69, respectively. Capital cost of the overpass is identical to that computed in Figure 63. The computation of the estimated benefit to cost ratio is given in Figure 70. The benefits from reduced vehicle operating costs are probably overstated in this analysis since turning vehicles would have to reduce speed to make the turn even without pedestrian conflict. A better approach to the estimation of benefit might have considered for turning vehicles only the incremental cost to stop from 15 or 20 miles per hour, rather than 30 mph.

7.3.3 Example No. 3 Involving the Reduced Cost of Alternative Crossing Controls

A study was conducted by the City of Los Angeles to evaluate the economic comparison of alternative controls at school crossings.(7) Using this study as a broad guide, the assumptions and computations related to pedestrian overpasses, crossing guards and traffic signals

ASSUMPTIONS:

1. Three pedestrian accidents have occurred at the projected site in the five year period preceeding the analysis.

2. The average city-wide fatality rate is 5.91 fatalities per 100 pedestrian accidents.

3. Assumptions (3) through (7) of Figure 64 apply except that approximately 50% of all pedestrians are children.

COMPUTATIONS:

1. The cost per child fatality is \$280,000 as computed in Figure 64.

2. The average cost of a fatality, weighted by adult and child pedestrian volumes is:

$$[(0.5)\ (\$34{,}400)] + [(0.5)\ (\$280{,}000)]$$

$$= \$17{,}200 + \$140{,}000 = \$157{,}200$$

3. The number of fatalities per year (see Figure 59) is:

$$\frac{1}{5}\ (3)\ (0.051) = 0.035$$

4. The number of injury accidents for year (see Figure 59) is:

$$\frac{1}{5}\ (3)\ (1.0 - 0.0591) = 0.565$$

5. The annual pedestrian accident benefit is given by:

$$B_3 = (0.565)\ (\$640) + (0.035)\ (\$157{,}200)$$

$$= \$360 + \$5500 = \underline{\underline{\$5{,}860}}$$

FIGURE 67

COMPUTATION OF PEDESTRIAN ACCIDENT BENEFIT
FOR EXAMPLE NO. 2 OVERPASS

ASSUMPTIONS:

1. The average number of vehicles delayed per day is 4461.
2. Approximately 22% of the vehicles are delayed an average of 10 seconds each by pedestrian actuation of signals.
3. Approximately 18% of the vehicles are delayed an average of 4 seconds each by pedestrians for pedestrian plus vehicle actuations.
4. Delays are encountered on 260 days per year, Saturdays and Sundays having negligible effects.
5. A value of $3.66 is used to compute the cost of vehicle delay (the product of $2.28 per hour per person - from the Stanford Research Institute study cited in Section 6.1.3 - and 1.3 persons per car).

COMPUTATION:

The benefit resulting from reduced vehicular delay is:

$$B_1 = \left(4461 \frac{\text{vehicles}}{\text{day}}\right) [(0.22)\ (10) + (0.18)\ (4)]$$

$$\times \left(\frac{\text{seconds}}{\text{vehicle}}\right) \times \left(\frac{260 \text{ days}}{\text{year}}\right) \left(\frac{\$3.66}{\text{hour}}\right)$$

$$\times \left(\frac{\text{hour}}{3600 \text{ seconds}}\right)$$

$$= (4461)\ (2.92)\ (260)\ (3.66)\ (1/3600)$$

$$= \underline{\underline{\$3{,}450}}$$

FIGURE 68

COMPUTATION OF VEHICLE DELAY BENEFIT FOR EXAMPLE NO. 2 OVERPASS

ASSUMPTIONS:

1. A value of \$0.0061 was used as the increased cost of vehicle operation to decelerate from 30 mph to a stop, or to accelerate to 30 mph from stop; this value is from AASHO, Reference (2).
2. The assumptions in Figure 68 apply.

COMPUTATION:

The benefit resulting from reductions in vehicle operating costs is:

$$B_2 = (4461 \frac{\text{vehicles}}{\text{day}}) (\frac{260 \text{ days}}{\text{year}}) (0.22 + 0.18)$$

$$\times (\frac{2 \times \$0.0061}{\text{vehicle}})$$

$$= (4461) (260) (0.4) (\$0.0122)$$

$$= \underline{\underline{\$5,660}}$$

FIGURE 69

COMPUTATION OF VEHICLE OPERATION BENEFIT FOR EXAMPLE NO. 2 OVERPASS

The benefit to cost computation is:

$$\frac{B}{C} = \frac{B_1 + B_2 + B_3}{C}$$

$$= \frac{\$3450 + \$5660 + \$5860}{\$5850}$$

$$= \frac{\$14970}{\$5850} = \underline{\underline{2.56}}$$

FIGURE 70

COMPUTATION OF THE BENEFIT TO COST RATIO FOR EXAMPLE NO. 2 OVERPASS

are shown in Figures 71, 72, and 73, respectively. The vehicular delays which effectively add to the cost of the latter two alternatives are not computed, but the relationships between the cost of the three choices will be clear. This analysis is characteristically a variable-cost, fixed-benefit type of comparison, where it is assumed that all alternatives are equal on the basis of benefit (excluding vehicle delay which is treated as a cost, where applicable); then comparison between alternatives is based strictly on cost.

On the basis of capital costs alone, the pedestrian overpass is preferred over the crossing guard alternative. Comparing the overpass with the traffic signals, the overpass will be the preferred alternative when

$1780 < $1630 + vehicle delay costs (from signals),

or when

vehicle delay costs (from signals) > $150 per annum.

ASSUMPTIONS:

1. Initial capital cost of an average pre-fabricated steel bridge is $25,000.
2. Annual maintenance cost is $160.
3. One right-of-way is costed at $1,500, the other end is assumed to be on school property.
4. The expected service life is assumed to be 50 years with no salvage value; and
5. A 6% interest rate is used.

COMPUTATION:

The tabulated capital recovery factor for 6% and 50 years is 0.0634; hence

C_1 = equivalent uniform annual cost for the pedestrian overpas

= [(0.0634) ($25,000 + $1500)] + $100

= $1,680 + $100 = $1,780

FIGURE 71

COMPUTATION OF THE UNIFORM ANNUAL COST OF A PEDESTRIAN OVERPASS FOR EXAMPLE NO. 3

ASSUMPTIONS:

1. Elementary school crossing guards will be required for 6 hours per day for 175 school days per year at a cost of \$2.00 per hour.
2. Vehicle delays represent a substantial cost which is incurred but not computed.

COMPUTATION:

C_2 = annual cost of school crossing guards

$$= \left(6 \frac{\text{hours}}{\text{day}}\right) \times \left(175 \frac{\text{days}}{\text{year}}\right) \times \left(\frac{\$2.00}{\text{hour}}\right) + \text{ delays}$$

$$= \underline{\underline{\$2{,}100 + \text{Vehicle Delay Costs}}}$$

FIGURE 72

COMPUTATION OF ANNUAL COST OF SCHOOL CROSSING GUARDS FOR EXAMPLE NO. 3

Since the cost of delay to vehicles will usually exceed \$150 per year under medium traffic flows, the conclusion reached is that the pedestrian overpass will often be the most economic solution to crossing at schools. Of course, the cost of the overpass computed here would have to be adjusted for the added cost of vehicle delay if utilization is low enough to require it. Also, if supervision of the students is a valid cost, it would have to be included.

ASSUMPTIONS:

1. Initial capital cost per signal is $10,000.
2. Annual maintenance cost is $600.
3. Expected service life is 15 years.
4. A 6% interest rate is used.
5. Vehicle delays represent a substantial cost which is incurred but not computed.

COMPUTATION:

The tabulated capital recovery factor for 6% and 15 years is 0.1029; hence

C_2 = equivalent uniform annual cost of school crossing signal (Note: this cost is independent of the reinvestment cycle of $10,000 each 15 years)

= (0.1029) ($10,000) + $600 + delay costs

= $1,030 + $600 + delay costs

= $1,630 + Vehicle Delay Costs

FIGURE 73

COMPUTATION OF ANNUAL COST OF TRAFFIC SIGNALIZATION FOR EXAMPLE NO. 3

7.3.4 Example No. 4 Involving Net Reduced Cost of Alternative Transportation Modes

In an Oklahoma City study,(8) a pedestrian overpass is considered across a four-lane divided expressway which has recently been added to the interstate system. Fencing will be installed to restrict pedestrian egress to the highway between two existing grade-separations located one mile apart. This will restrict movement by students from a residential area located on one side of the highway to a junior high school located on the other side; the highway bisects the school district and a change in the school district boundary is not considered to be feasible.

The proposed overpass will reduce overall student trip distances and times sufficiently to allow them to walk to school. Without the overpass, distances will be too great, and busing or car pooling will have to be provided. The economic comparison of several alternatives is given in Figures 74 through 78. Note that this analysis is similar to that described in Section 7.3.3 in that each alternative is considered to be equally beneficial; comparison is made solely on the basis of cost.

The cost of the underpass computed in Figure 74 is somewhat understated due to the omission of annual maintenance and an annuity due to the purchase of some required right-of-way, but even if these added costs are taken into consideration, the only other competing alternative is that of school owned and operated buses costed in Figure 76. Note that the latter cost is also understated by about $540 per year due to not considering the annuity (at 6%) in computing the cost of the buses. However, school ownership and operation of the buses is not considered to be a viable alternative since the school has no facilities or program for such an undertaking. Hence, the overpass is clearly the preferred alternative based on the data presented.

7.3.5 Example No. 5 Involving the Impact of Improved Linkage of Neighborhoods and Related Considerations

The pedestrian overpass described in the preceding section (7.3.4) was subsequently built. An analysis,(8) made about one year after the structure was opened, revealed that actual pedestrian use in terms of the number of trips exceeded anticipated use estimated during the economic justification analysis. The overpass was also accommodating bicycle trips that could not have been made previously

ASSUMPTIONS:

1. Initial capital cost of the overpass is estimated to be \$63,000.
2. Expected service life is 40 years.
3. A 6% interest rate is used.

COMPUTATION:

The tabulated capital recovery factor for 6% and 40 years is 0.0665; hence

C_1 = equivalent uniform annual cost of the overpass

= (0.0665) (\$63,000)

= \$4,200

FIGURE 74

COMPUTATION OF ANNUAL COST OF THE OVERPASS FOR EXAMPLE NO. 4

ASSUMPTIONS:

1. Approximately 150 students will require busing.
2. Contract bus service will require two buses making two trips each per day at $13.00 per trip.
3. Student bus fare will be $0.10 per student per trip.
4. The annual school year is 175 days.

COMPUTATION:

$$C_2 = \text{annual cost of contract bus service}$$

$$= \text{cost of buses} + \text{cost of student fares}$$

$$= [(2 \text{ buses}) \times (\frac{2 \text{ trips}}{\text{bus.day}}) \times (\frac{\$13.00}{\text{trip}}) \times$$

$$\times (\frac{175 \text{ days}}{\text{year}})] + [(150 \text{ students}) \times$$

$$\times (\frac{2 \text{ trips}}{\text{student.day}}) \times (\frac{\$0.10}{\text{trip}}) \times (\frac{175 \text{ days}}{\text{year}})]$$

$$= \$9,100 + \$5,250$$

$$= \underline{\underline{\$14,350}}$$

FIGURE 75

COMPUTATION OF ANNUAL COST OF CONTRACT BUS SERVICE FOR EXAMPLE NO. 4

ASSUMPTIONS:

1. 60 passenger bus list price is \$7,500.
2. Expected service life of bus is 10 years with zero salvage value.
3. Length of average bus route is 4 miles per trip.
4. Driver's wages per trip are \$3.00.
5. The annual school year is 175 days.
6. Bus operating costs (including stops) are \$0.65 per mile (source is AASHO Manual of road user costs).

COMPUTATION:

C_3 = annual cost of school owned and operated buses

= cost of buses per year + cost of operation per year.

$$= (2 \text{ buses}) \left(\frac{\$7500}{\text{bus}}\right) \left(\frac{1}{10 \text{ years}}\right) + \left(\frac{175 \text{ days}}{\text{year}}\right)$$

$$\times \left(\frac{2 \text{ trips}}{\text{day.bus}}\right) (2 \text{ buses}) \left[\left(\frac{4 \text{ miles}}{\text{trip}}\right) \left(\frac{\$0.65}{\text{mile}}\right) + \left(\frac{\$3.00}{\text{trip}}\right)\right]$$

$$= \$1,500 + (700)(\$5.60) = \underline{\underline{\$5,420}}$$

FIGURE 76

COMPUTATION OF ANNUAL COST OF SCHOOL OWNED AND OPERATED BUS SERVICE FOR EXAMPLE NO. 4

ASSUMPTIONS:

1. Annual cost of bus leasing is $1,800 per bus.
2. Annual cost of insurance is $150 per bus.
3. Annual wages for bus drivers are $1,050 per driver.
4. Annual cost of gasoline is $300 per bus.
5. Annual cost of oil is $35 per bus; and
6. Annual taxes are $200 per bus.

COMPUTATION:

C_4 = annual cost of two school leased and operated buses

$$= (2 \text{ buses}) [(\$1800 + \$150 + \$1050 + \$300 + \$35 + \$200)]$$

$$= (2) (\$3535) = \underline{\underline{\$7,070}}$$

FIGURE 77

COMPUTATION OF ANNUAL COST OF TWO SCHOOL-LEASED-AND-OPERATED BUSES FOR EXAMPLE NO. 4

ASSUMPTIONS:

1. 50 round trips of 2.954 miles per trip, plus

   17 round trips of 3.014 miles per trip, plus

   15 round trips of 2.600 miles per trip will be required twice a day to transport students by car.

2. Vehicle operating cost is $0.168 per mile.

3. The school year is 175 days.

COMPUTATION:

C_5 = annual cost to provide student transportation by passenger car

$$= \left(\frac{175 \text{ days}}{\text{year}}\right) \left(\frac{\$0.168}{\text{mile}}\right) \{(2)\ [(50)\ (2.954) + (17)\ (3.014) + (15)\ (2.600)]\}\ (\text{miles})$$

$$= (175)\ (\$0.168)\ (2)\ (237.93) = \underline{\underline{\$13,990}}$$

FIGURE 78

COMPUTATION OF ANNUAL COST OF TRANSPORTING STUDENTS BY PASSENGER CAR FOR EXAMPLE NO. 4

because of the severe safety risk. Lastly, the actual structure cost resulted in an annual cost of $4,258, extremely close to the estimated value of $4,200.

The following discussion is abstracted from the actual before and after experience contained in the Oklahoma study. It is included to provide some insight into the facility impact; actual figures are used only to provide visibility to the concepts. Some simplifications have also been made by concentrating on the notion of school trips (although trips were actually made by other than students), and by combining pedestrian and bicycle trips into one category; otherwise the discussion would have been unnecessarily complicated. Hence, when pedestrian or walking trips are mentioned, it should be understood that this means student school trips by either foot or bicycle.

The discussion centers on curves such as those shown in Figure 79; the concepts related to the curves have been discussed in Section 5.2.1. In general, Figure 79 illustrates the relationship between the propensity to walk and trip impedance, in this case, walking distance.

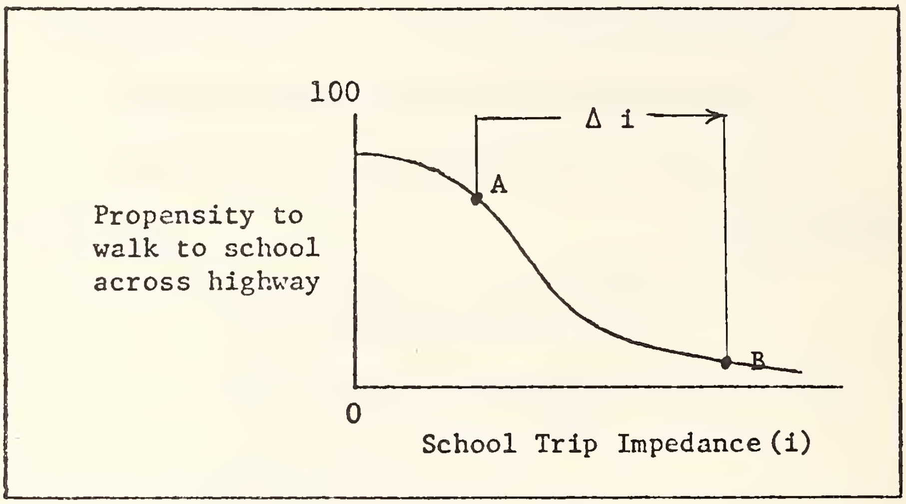


FIGURE 79

PROPENSITY TO WALK VERSUS DISTANCE

On the vertical scale a value of 100(%) indicates that all pedestrians are willing to walk; a value of zero indicates that no pedestrians are willing to walk. The actual shape of the curve shown in Figure 79 will vary under the influence of weather, trip purpose, etc.; for this discussion the actual trace is unimportant.

In the Oklahoma study, the situation prior to construction of the overpass or installation of fencing to prevent pedestrian movement across the roadway was that approximately 75 actual trips in a potential 200 trips were being made each day across the busy, divided highway. This can be represented by point "A" on the curve shown in Figure 79. It is assumed that the other 125 trips are being made via existing separations located one mile apart at each end of the study area, or are being made using alternative modes of transportation.

Installation of fencing to prevent student movement across the highway will substantially increase the trip impedance (average walking distance to school) causing many students to transfer to other transportation modes rather than walk the often prohibitively long distances. This effect is illustrated by point "B" in Figure 79.

When the pedestrian overpass was installed, the average walking trip length to school was reduced. However, the combination of the overpass and fencing still represented a constraint over the unconstrained base condition represented by point "A". Therefore, the overpass will theoretically induce an increase in the student propensity to walk to school because of the decrease in impedance due solely to the reduced trip time, but it will not exceed that presented by point "A". The propensity increase due to the overpass, shown as point "C" in Figure 80, ignores the notion that trips via the facility now represent safer trips.

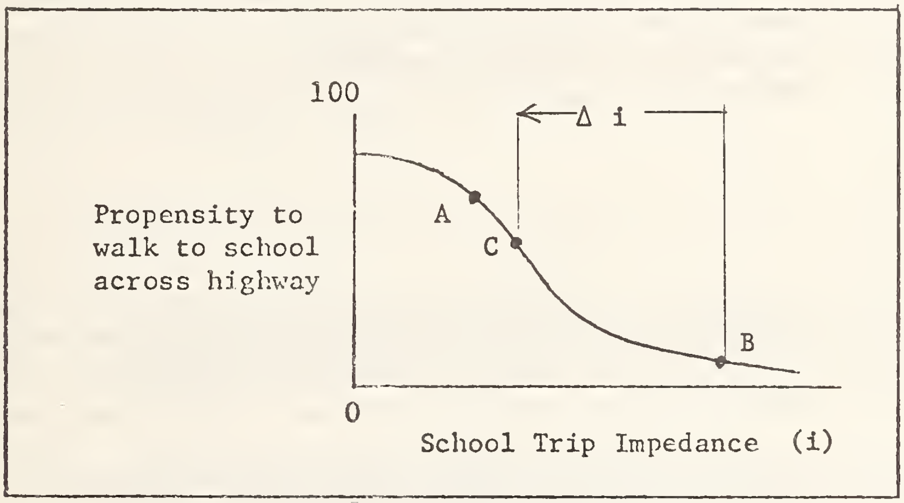


FIGURE 80

REDUCED IMPEDANCE DUE TO CONVENIENCE
OF OVERPASS ONLY (POINT C)

The increase in walking trip propensity represented by the distance "C" - "D" on Figure 81 shows the additional impact due to safety and explains the increase in bicycle trips and resultant increase in all school trips uncovered in the follow-up study. It is also reasonable to assume that some of the trips represented by "A" - "D" were previously made by other modes of transportation, and that the facility

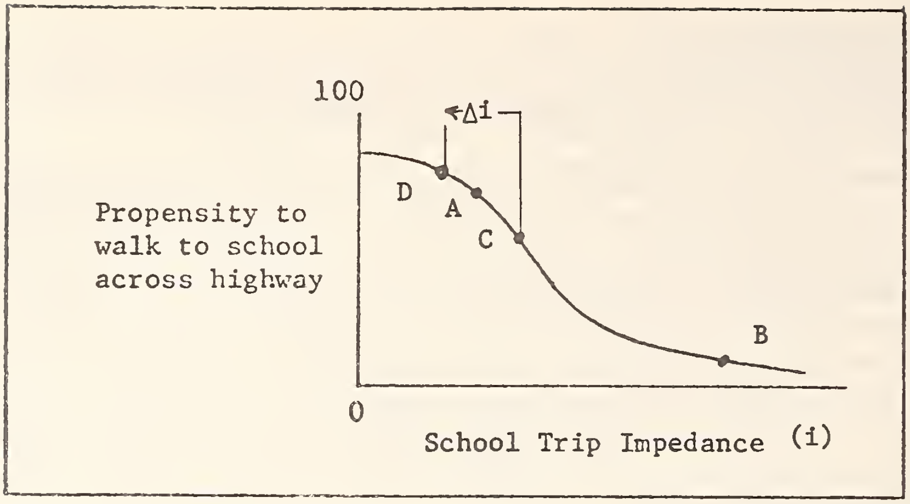


FIGURE 81

ADDED REDUCTION OF IMPEDANCE DUE TO INCREASED SAFETY OF OVERPASS (POINT D)

has effectively incurred a net benefit due to walking over other means. Lastly, it is obvious that the neighborhoods are now more adequately linked; walking trips have been generated including trips (other than to school) to a shopping center, playing fields and a swimming pool.(8)

7.4 COMPARISON OF OVERPASSES VERSUS UNDERPASSES

In a given situation, the primary alternatives related to a highway crossing are whether to go over or to go under. In many instances, the choice is dictated by the site itself; for example, a bridge over a depressed highway is an obvious choice as is a tunnel under an elevated highway. While circumstances can vary between these two extremes, the choice is usually only relevant when a crossing for an at-grade highway is proposed.

In terms of potential benefit, the alternatives are equal, with the exception that tunnels usually offer slightly shorter crossing routes since the necessary change in-grade is less than for bridges; also, tunnels offer some protection against inclement weather. However, these benefits are negligible when compared to those that related to increases in safety, reduced vehicular delay, and shortened overall pedestrian trip length which accrue equally to either alternative.

The key consideration is not one of potential benefit, but one of the extent to which benefits are reduced, due to less than full utilization. If pedestrians still choose to cross at-grade because they perceive the facility as an impedance, then benefits are degraded accordingly. For facilities to realize the benefits for which they were built, barriers or similar devices that encourage utilization by discouraging at-grade crossing are necessary.

Given that utilization is enforced thereby making either alternative equally beneficial, the choice can be made on the basis of cost. The choice is clearly in favor of the overpass solution, except when the underpass will be built in conjunction with an existing highway; if site contingency costs, due to excavation problems, exist, the underpass costs would be escalated accordingly, and the overpass would remain the clear choice. These effects would be brought out by a detailed cost analysis of the proposed facility taking into account the cost factors discussed in Chapter 3.

The following list summarizes several of the key points regarding underpasses versus overpasses:

- underpasses require less change-in-grade (approximately 10 feet) than overpasses (16 feet);

- short, wide tunnels serving large numbers of people, primarily during daylight hours are utilized without problems (sports events, factory workers, etc.);

- where use at night is anticipated, underpasses are discouraged, due to potential security problems; and

- underpasses tend to collect debris and could require more annual maintenance then overpasses.

CHAPTER 7 REFERENCES

(1) Institute of Traffic Engineers, "Pedestrian Overcrossings - Criteria and Priorities," Traffic Engineering, October 1972.

(2) American Association of State Highway Officials (AASHO), Road User Benefit Analysis for Highway Improvements, Washington, D. C., 1960.

(3) R. Winfrey, Economic Analysis for Highways, International Textbook Company, 1965.

(4) U. S. Department of Transportation/National Highway Traffic Safety Administration, Societal Costs of Motor Vehicle Accidents (Preliminary Report), April 1972.

(5) City of Seattle, Topics-Project Prospectus (Revised) for Aurora Avenue-North Project, 18 November 1969.

(6) City of Seattle, Topics-Project Prospectus (Revised) for Pedestrian Overpasses (2) Project, 21 November 1969.

(7) City of Los Angeles Department of Traffic, "An Economic Comparison of Pedestrian Overpasses, Crossing Guards and Traffic Signals at School Crossings," Staff Report.

(8) Oklahoma Highway Department, Before and After Study: Pedestrian Grade Separation at Southwest 74th Street (I-240) and South Blackwelder Avenue in Oklahoma City, Oklahoma, May 1972.

CHAPTER 8. GRADE SEPARATION IN CENTRAL BUSINESS DISTRICTS

8.1 INTRODUCTION

The central core of most cities represents an intense concentration of activities which are interrelated and depend on interpersonal contact for their vitality. The physical and functional characteristics of many downtown areas consist of antiquated street systems surviving from a past distribution of land use. Most street and sidewalk systems were originally designed to serve a certain size population and land use configuration. Presently, these same systems, as a result of environmental growth, serve a larger population and significantly different magnitude and distribution of land use. Coupled with the increased amount of urban space devoted to vehicular movement, these factors have combined to produce an environment which is vastly incompatible with pedestrian movement.

The pedestrian, however, is necessary to the survival of downtown. It is not until the driver parks his car and begins his walking trip that the potential for the activity that makes downtown vital is realized. The conflict that exists between the pedestrian and the vehicle not only causes congestion, discouraging both walking and driving, but acts to negate many of the economic, social, political and physical forces that hold downtown together. The result, in many cases, has been a shift in activity to the suburbs where the opportunity for pedestrian-vehicular separation has been enacted; witness the complete vertical and/or horizontal separation concepts that help to make suburban shopping centers a success.

One response to the problem of movement conflict in downtown is the provision of separate circulation systems for pedestrians and vehicles. Pedestrian systems, often conceived and implemented as part of downtown redevelopment and improvement programs recognize three basic principles:

- the need to return to a human scale in the city;
- the need for direct human interaction and communication; and
- the need for urban space to serve its users free of conflict.

8.2 THE CASE STUDY APPROACH

Appendix A is devoted to a discussion of pedestrian separation in urban central business districts. The approach used is that of providing expanded case studies of several systems that have been implemented. CBD systems, by virtue of their extensiveness, are far more complex than singular system elements such as over-street bridges, and hence, are more difficult to evaluate. The case study approach allows a broad-based discussion of many of the diverse factors that influence their development. In addition, this approach is not severely hampered by the following facility analysis:

(1) limitations on the existence of specific site-related evaluative data;

(2) an almost unlimited number of possible system combinations;

(3) the highly site-related nature of the facility solutions;

(4) the evolutionary development process applied in most cases; and

(5) difficulties of separating sub-system effectiveness from that of the system.

Data limitations are discussed in the next section. The second constraint results from the way in which horizontal and vertical elements are combined to meet the needs, services and characteristics of a given urban area. The number of combinations is as numerous as the possible variations in land use and transportation network structures common to downtown; there is virtually no way to generalize these systems. The third and fourth constraints are related to the concept that numerous factors interact to influence every aspect of the conception, design, implementation and operation phases of large-scale urban pedestrian systems. The planning process is a continuum that includes the dynamics of public and private leadership, the political climate, and the location and timing of urban renewal and private development, in addition to the cost and benefit impacts of pedestrian facilities. Many pedestrian systems are conceived simply because the opportunity for new development exists; the situation where abutting development responds to the implementation of a walkway system has been true on a small scale, but not in general. The successful pedestrian systems are those which complement adjacent development rather than presuppose it.

From an evaluative standpoint, it is difficult to determine at what point in the planning process the examination of cost and benefit should occur. Most systems are in a constant state of expansion (which says something for their success). Expanded systems tend to incur benefit that exceeds the sum of the parts. This brings up the last constraint; it is impractical to evaluate system elements without considering the system as a whole. An unsuccessful system link may suddenly become highly utilized due to the addition of another connection, hence the question of that link's benefit cannot be separated from the benefit of the system as a whole. For these reasons, along with the discussion of data in the next section, it was considered appropriate to use a case study approach that allows for the discussion of a broader range of the dynamics of pedestrian impacts.

8.3 DATA SURVEYS, LIMITATIONS AND RECOMMENDATIONS

The first constraint -- that of data limitation -- is the most important. Data which indicates the impact of pedestrian facilities in the CBD on pedestrian safety or reduction of vehicular delay is nonexistent in any useful form. Retail impacts are extremely difficult to obtain, and are not readily available. Pedestrian convenience and comfort impacts are usually discernible from the configuration of the system itself, but require a comprehensive physical inventory. The one area that is almost totally overlooked is that of facility pathway utilization as compared to that of alternative vehicle-dominant pathways.

An extensive survey of sites having proposed or existing pedestrian facilities was made to ascertain the availability of useful cost and impact data. The following conclusions are based on experience gained in making the survey:

(1) The availability of secondary sources of data related to specific facility impacts is severely limited.

(2) Where secondary data are available, they are generally inadequate for determining the facility impacts.

(3) Primary data can be obtained.

(4) The availability and suitability of relevant data for use as a baseline prior to implementation of the pedestrian facility represents the major analytical constraint.

The first conclusion results directly from the data availability survey. It was found that of 116 specific facilities polled, only 24 indicate the existence of any impact data. Of the facilities that did indicate the availability of impact data, the coverage was spotty; several pointed out the low level nature of the evaluations.

The second conclusion was reached by examining information obtained by mail, and by an in-depth analysis of the one site that appeared to be the most favorable -- Minneapolis. It should be noted that most sites indicating impact data were contacted by phone, and the nature of the information discussed in detail; this often revealed the inadequacy of the available material. In no instance was any information discovered which explicitly examined the impact of a facility on pedestrian safety or vehicular flow; only in Montreal has a qualitative statement suggesting a positive impact of that city's extensive facility been made. Pedestrian convenience and comfort have been addressed in some cases, but no adequate conclusions on impact can be drawn. Abutting property and municipal impacts have received the most attention, but primarily as they relate to at-grade malls; and even here the feeling is that only the positive impacts get adequate coverage.

The conclusion that primary impact data can be prepared is based on examination of the limited amount of secondary information reviewed. The impact of a facility on pedestrian safety and vehicular movement will be the most difficult to measure because of the problem of obtaining an effective base line as expressed in the last conclusion. Modifications in the street network, revisions to the parking patterns, and similar changes that usually accompany the implementation of pedestrian facilities will further complicate the determination of these impacts. The other impacts can be adequately measured using existing primary sources supplemented by additional data collection and analysis.

Based on the conclusions cited above, the following recommendations are offered for future consideration:

1. That comprehensive evaluations be conducted for specific pedestrian accommodations, to include a physical inventory, pedestrian origin and destination surveys, an analysis of pedestrian accident data, and collection and analysis of property values, private sector economic measures and related data;

2. That potential sites for future pedestrian facilities be examined for the purpose of establishing base lines against which impacts resulting from subsequent implementation of these facilities can be evaluated, particularly as related to vehicular movement and economic trends; and

3. That further research be directed toward understanding the nature of the conflict between pedestrians and vehicular traffic flow, primarily as it relates to delays.

The suggestion related to comprehensive facility studies is the primary one due to the lack of adequate secondary data for evaluation. Ideally, these evaluations would be conducted by, or with the cooperation and possible assistance of, local agencies. A detailed table of required data elements is shown in Figure 82. The physical inventory would provide the basis to support the subsequent data collection and analysis. The origin and destination surveys are essential to an understanding of facility utilization and its related factors. Accident data would allow the testing of hypotheses concerning facility impact on pedestrian safety. The property values, economic measures and related data would support analysis of facilities impacts on land use, and municipal and private sector economies.

Of course, the first objective of the in-depth facility evaluations would be to determine the cost and effectiveness impacts of the facility. However, as is further suggested, the information gained at existing sites could also be used to structure requirements and procedures for use at potential sites in other cities to establish a data base line to support later evaluation of the facility. This would serve to further define the impacts, as well as enhance subsequent evaluations.

PHYSICAL INVENTORY

- Physical Layout (MAP)
- Location and Description of Primary Generators
- Location and Description of Secondary Generators
- Path Distance and Time Measures
- Type, Extent and Location of Vertical Change Elements
- Points of Pedestrian/Vehicular Conflict
- Obstacles to the Handicapped
- Lighting Levels and Other Security-Related Data
- Description, Location and Extent of Activity (Retail, Commercial, Non-Active, etc.)
- Description and Location of Signing

ORIGIN AND DESTINATION SURVEYS (PER PEDESTRIAN TRIPS)

- Origin and Destination of Trip
- Route Description
- Time and Day of Trip
- Trip Purpose
- Trip Frequency
- Trip-Maker Characteristics
- Arrival and Departure Mode
- Reason for Selecting Trip Route
- Attitudes Toward Facility
- Percent or Amount of Non-Food Purchases (for shopping trips)

(NOTE: Weather and any special conditions affecting path choice such as broken escalators, street excavation or facility closure should be recorded to augment the pedestrian O-D surveys)

CONFIDENTIAL RETAIL MERCHANT SURVEYS (PER RETAIL ENTITY)

- Actual Time-Phased Sales Impacts (quarterly or annual sales)
- Percentage Comparison of Sales (in lieu of actual sales)
- Percent of Sales Contributable to Facility
- Observed Changes in Consumer Age Groups
- Observed Changes in Consumer Income Groups
- Observed Changes in Consumer Employment Groups
- Changes in Store Business Hours
- Changes in Store Inventory Policies
- Changes in Store Promotional Intensity
- Changes in Store Market Segment
- Attitudes Toward Facility
- Recommendation Regarding Facility Improvement
- Changes in Trade Area Configuration

ECONOMIC IMPACT MEASURES (MOST ARE TIME-PHASED)

- Property Values (adjusted to price level changes)
- Capital Investment (and Reinvestment)
- Occupancy Rates
- Current to Optimal Utilization Ratios
- Changes in Property Ownership Patterns
- Space Conversion Related to Facility
- Type and Quantity of Gross Space
- Costs of Ancillary Services (e.g., parking)
- Tax Assessment Records
- Rental Costs per Square Foot
- Net Additions to Tax Base
- Revenue from Taxes
- Special Assessments
- Cost of Municipal Service Provision
- Property Cost Verus Total Property Value

ENVIRONMENTAL MEASURES

- Perceptual Factors (from surveys) - Image, Attractiveness, Visual Intrusion
- Noise and Air Pollution Measurements
- Compatibility of Connected Land Use Activities

FIGURE 82

FACILITY EVALUATION DATA ELEMENT REQUIREMENTS

The problem of delays to vehicles due to pedestrians, and to pedestrians due to vehicles, especially in the CBD, is a singular one. Relevant research is nearly nonexistent. Some studies have indicated the obvious -- that delays are incurred, but no comprehensive understanding of the variables and their behavior is available. Simulation techniques appear to offer advantages over other techniques, such as multivariate regression, and should be considered further.

The primary purpose of the pedestrian origin and destination surveys would be to determine the extent of facility utilization relative to alternative paths. Utilization is the key to the determination of facility benefits. If pedestrians do not use facilities provided for them, benefits do not accrue -- pedestrian/vehicular conflicts are not reduced, vehicle delays remain unchanged (or worsen), and pedestrian activity is not increased to the extent that retail and municipal benefits are realized. As discussed in Chapter 5, utilization of facilities depends on elements of facility design, such as continuity and lighting, as well as on the pedestrian's own perception of the benefits to be derived by using the facility. It is this relationship between facility design and pedestrian choice that should be examined using data that can be obtained only through well-designed pedestrian origin and destination surveys for different types of conditions and environments.

Lastly, the determination of facility impact on adjacent properties and its related effects is hampered by difficulties in obtaining primary data. Merchants are reluctant to disclose retail data, and other measures are usually buried within the profusion of statistics maintained by a multitude of different agencies. There is also the difficulty of developing measures at a sufficiently low level to isolate the impact of a specific facility or facility element. However, data elements collected for studies of malls by means of confidential retail merchant surveys, consumer surveys, and available public records have provided the basis for excellent impact analyses. The list in Figure 82 reflects the types of information required.

8.4 ALTERNATIVE SYSTEM CHOICE

For the purpose of this report, the primary alternatives for the central business district are above-grade and below-grade systems. In practice, a choice based on the cost and benefit of alternatives can only be made when configurations designed to suit the specific proposed location have been completed. In general, if two systems having the same basic configuration -- one above-grade and the other below-grade -- are compared, they will both have the same effectiveness (utilization notwithstanding), and will yield the same basic benefits; hence, choice would be based strictly on alternative costs. This idealized situation will be the exception rather than the rule. In most cases, alternatives will be configured in vastly different ways and will yield different benefits due to the impacts of pathway design attributes on utilization.

Advantages and disadvantages of above- and below-grade systems are discussed in Chapter 2; an elementary comparison of street crossing elements is given in Section 3.3.7. The following general statements regarding CBD system benefits and choice are a result of observation and discussions with planners and developers associated with one or more of the systems discussed in the next section. They are offered as guidelines to augment the necessary detailed analysis that would precede any large-scale development project such as a CBD pedestrian system.

(1) Underground (below-grade) systems will be the preferred alternative only under the following conditions:

- there is an extensive and compatible below-grade system, such as a subway, existing prior to the proposed development in the project area;

- the proposed walkway development is being planned in conjunction with extensive new commercial development (see Montreal);

- problems with utility relocation, water table, rock and similar below-grade contingencies are minimal; and

- an above-grade system is simply not feasible.

(2) The most successful CBD pathways are direct, short, lined with retail shops, and anchored at both ends by large pedestrian generators, ideally department stores or mode-transfer points.

(3) Comfort is probably the most significant variable affecting pedestrian pathway choice and utilization.

(4) In the CBD, safety has only a minimal impact on benefit or utilization.

(5) The largest components of benefit are reduced vehicular congestion and delay and stimulation of retail activity.

(6) System success is directly related to extensiveness and connectivity of diverse land uses.

(7) Walkway implementation should be phased by introducing additional links over time.

(8) Successful systems result from strong, cohesive civic leadership and cooperation among public and private interests (see Minneapolis); alternatively, they result when large parcels of urban core land are under single ownership and can be developed as a system (see Montreal).

8.5 CASE STUDIES

In the following sections, case studies of the following central business district pedestrian systems are provided:

- Montreal: One of the most extensive pedestrian systems in the world. It serves as an excellent illustration of the potential for separation of all modes -- pedestrian, vehicular, trucking, rapid transit, rail -- when a vital downtown area is developed as a single unit. The system represents a high degree of phasing, a highly developed and concentrated retail orientation, and the maximum in year-round comfort.

- Toronto: Although not fully connected or developed, stands as an example of the way in which civic agencies can provide leadership and participation to effect control and stimulate cooperation between a diverse set of public and private interests.

- Minneapolis: Actually two systems, a unique midblock skyway system integrated in a very limited way with a highly successful mall. The skyway system features a highly refined sequence of phasing, a concentration of rental activity and the maximum in year-round comfort. Being a privately constructed and operated system connecting both new and old development, there is a lack of municipal control and uniform orientation; accessibility and availability are limited.

- Cincinnati: A totally public elevated walkway with 24-hour access through both public and private spaces; it connects a more diverse land use configuration than found in most treatments. Walkway phasing is slightly ahead of private development, and strong municipal controls result in consistent orientation and public-private design coordination. Being an open system, the walkway lacks protection from heat and cold. There is a heavy reliance on vertical elements of movement, and certain areas of the system lack adequate visibility resulting in the potential for security problems.

- Lancaster: Provides an example of the way in which exogenous factors related to phasing and timing of walkway development, out of context with adjacent private development, have acted to negate an otherwise effective pedestrian system.

APPENDIX A

CASE STUDIES OF CBD PEDESTRIAN FACILITIES

A. 1 MONTREAL

A. 1. 1 Historical Background

The development of the Montreal pedestrian system began in a core of three contiguous blocks, covering approximately 22 acres, owned in its entirety by the Canadian National Railway (CNR). This three-block area as it is presently configured is shown in Figure A-1.

Plans for overall development of this three-block area date back to the 1920s, but it was not until the early fifties that circumstances arose that led to the present day complex. Writing in Skyscraper Management,(1) Vincent Ponte, an urban planner who was one of the men responsible for the Montreal system, describes the historical sequence of events:

> "As far back as the late 1920s, the railway's first President, Sir Henry Thornton, influenced by the Grand Central/Park Avenue complex in New York City, laid down the principle that the property between Cathcart and St. Antoine Streets should be developed according to a master plan. His idea for huge 10-story office buildings, covering entire blocks, like many grandiose schèmes of that day, collapsed with the financial crisis of 1929. The ensuing years of depression and then the Second World War held development in abeyance for some 20 years. By 1949, only the CNR Central Station and one small office building had been built on the land. The rest remained a great open hole in the ground, exposing the sunken railroad tracks which ran through the city.
>
> "Two key decisions started Montreal moving. The first one, made by the city, was to widen Dorchester Boulevard (accomplished 1954) and make it the main thoroughfare for Montreal's predominant East-West flow of traffic. The other, made by Donald Gordon, the CNR's recently retired president, was to build the 1,200 room Queen Elizabeth Hotel fronting on this new boulevard.

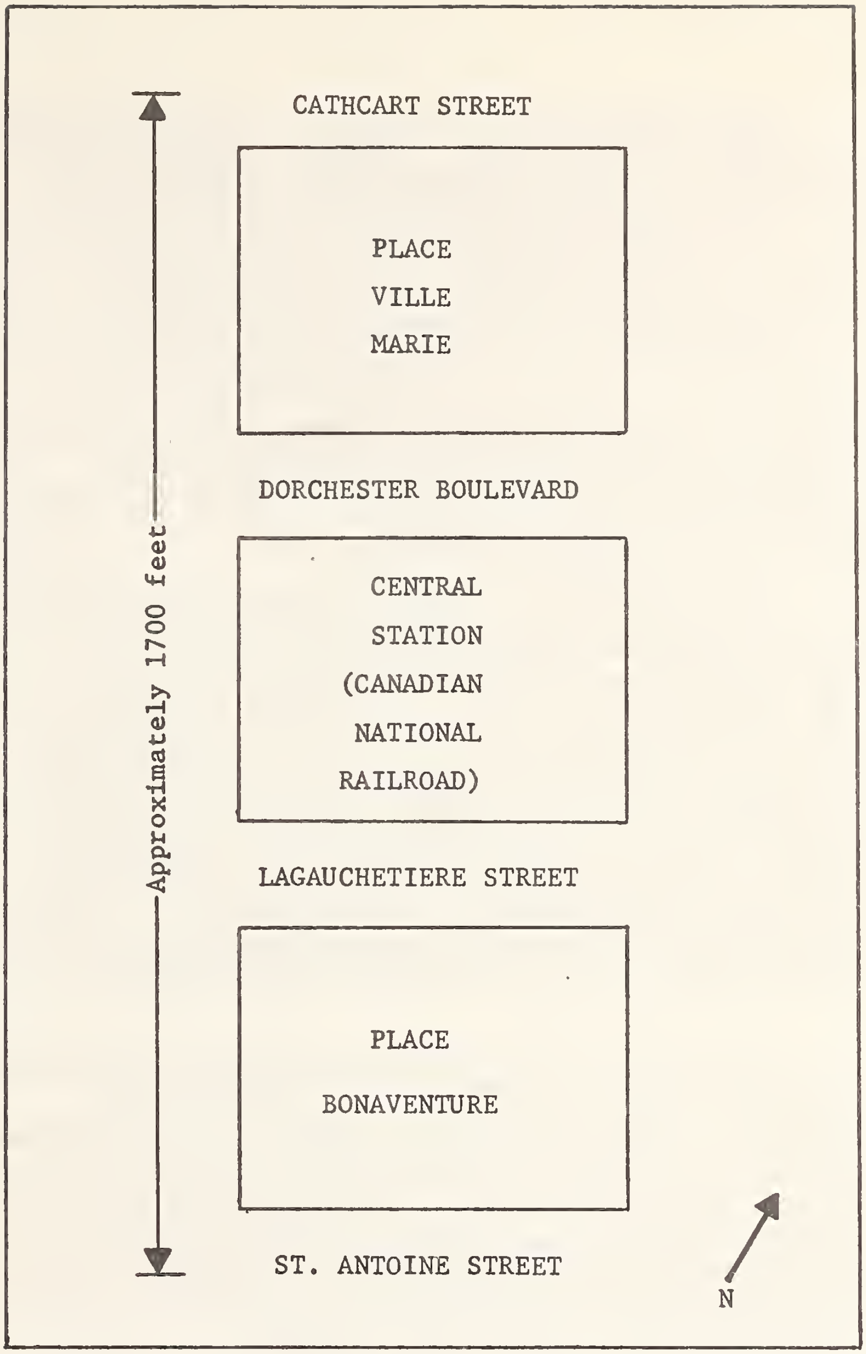


FIGURE A-1

CENTRAL CORE AREA OF THE MONTREAL PEDESTRIAN SYSTEM

"While the hotel was abuilding, next to the still-gaping great hole, Gordon brought in another man of vision, the developer William Zeckendorf, to produce a master plan for the entire three-block area, including the hole. In line with Sir Henry Thornton's precepts, Gordon insisted that the properties should be developed as a unit and not piecemeal. Zeckendorf immediately saw that the CNR land, standing squarely in the path of Montreal's moving center of gravity, could, if developed functionally and with grandeur, lift Montreal to the stature of a great metropolis.

"Zeckendorf's plan was accepted in 1957 by the CNR and he concluded a 99-year lease for development of one block of the three - namely Place Ville-Marie - to be improved as designed. The basic land rent for seven acres was $168, 884 annually, plus 10 percent of the revenue from the improvements. Less than a year after the signing of the lease construction began and the great hole with its railway tracks rapidly disappeared beneath the cruciform skyscraper, the broad plaza and its surrounding cluster of related office buildings.

"Until Place Ville-Marie, the city had been absorbing about 300, 000 sq. ft. of office space annually. Now, all at once, it gained an additional 1.5 million sq. ft. of office space, 70, 000 sq. ft. of shops at plaza level, 165, 000 sq. ft. of retail space under the plaza and two parking levels of 1, 000 stalls sandwiched between the shopping level and the railway tracks. This was an enormous amount of space for the city to absorb at one time and many prophesied that Montreal would choke on it. But when the late James Muir, President of the Royal Bank of Canada, decided to move its St. James Street headquarters to the cruciform skyscraper, the success of Place Ville-Marie (PVM) was assured. His decision placed the country's greatest bank at the most identifiable spot in the nation. Place Ville-Marie, the biggest of the post-war investments, $110, 000, 000, became the symbol of the new city and an instant magnet for

> further development. Two of the more important new buildings that began to cluster about the PVM center were the 43-story Canadian Imperial Bank of Commerce and the 34-story CIL House. Both of these buildings opened their doors in the same year as PVM. They added to the office rental market almost 1.5 million sq. ft., on top of that Place Ville-Marie was offering - and they rented!"

The success of Place Ville-Marie was to spark a succession of development which continues to this day. The tens of thousands of people attracted to Place Ville-Marie and neighboring buildings created a problem for the Montreal transportation system; ironically, these same buildings generated millions of dollars in new tax revenue enabling the City to borrow funds to built a much-needed subway system that had been talked about for 50 years.(2) Place Bonaventure to the south was opened and added an additional 3.25 million sq. ft. of development and an additional segment of pedestrian ways. Recent and proposed development is extending to the east of Place Bonaventure to Place Victoria and Place de la Bourse and to the west Place du Canada and the Windsor Station of the Canadian National Railway. In the future, the Montreal core is expected to extend to the north with retail development so that by 1985, it is predicted that 100 acres of the 185-acre Montreal downtown will be linked with over six miles of climate-controlled walkways.(2)

A.1.2 The Montreal Pedestrian System

In the three-block area shown in Figure A-1, there are essentially several systems, each coordinated with the other to provide maximum separation of pedestrians from other modes of transport. Within Place Bonaventure, for example, the subway, railway, major roadways, and pedestrian traffic co-exist at different levels unconstrained by the movement of each other.(1) The needs of parking and trucking are also independent, separated in both vertical and horizontal directions. The major integrating element is the pedestrian system which provides access to the other systems. In general, this access can only be achieved from the pedestrian system. All exits from parking spaces for pedestrians are into the system rather than directly to the street, and major connections to the subway and railway are from within the pedestrian system. Since the system itself provides adequate access to retail stores, office buildings, and other pedestrian activity centers, the design discourages pedestrian movement at street level in conflict with vehicular traffic while not creating problems for the pedestrian; this tends to assure the maximum benefits related to safety and congestion.

Figure A-2 illustrates the Montreal pedestrian system.

The major core of existing walkway development is in the three-block section consisting of Place Ville-Marie on the north (actually northwest), the central station block, and Place Bonaventure on the south; coupled through the Bonaventure Metro Station on the west to walkways within Place du Canada and to the Windsor railway station. This is the system that will be discussed in subsequent sections. Surrounding the core system, additional pedestrian system development has taken place; in most cases, interconnections are planned for the future. To the east of Place Bonaventure, a pedestrian system connecting the Place de la Bourse, Place Victoria, and other development to the north has been effected using the Victoria Metro Station it is expected that this will subsequently be connected to the core system. To the north, two major department stores are connected through the McGill Metro Station. Some minor developments of walkways has also taken place in conjunction with the Peel Metro Station to the northwest.

The core pedestrian system beginning at Place Ville-Marie is underground, but due to a sloping grade to south along the main three-block spline, it is at street level through the CNR Central Station block, and above grade within Place Bonaventure. Hence, the grade changes while the pedestrian circulation remains nearly horizontal, thereby creating three levels relative to the at-grade reference. To the west, the Bonaventure Metro Station is far below grade thus requiring substantial vertical change when access is made to or from Place Bonaventure, Place du Canada or the Windsor railway station. From within, the system has the distinct feeling of being underground.

The pedestrian trip attraction and generation potential of the elements connected by the system is extremely high. The Central railway station is responsible for tens of thousands of trips per day, many of which are to or from the shops and offices connected by the system. Trips are also related to the Windsor Station and the Bonaventure Metro Station. Place Ville-Marie alone has a total of nearly 2.75 million square feet of floor space which includes 1.5 million

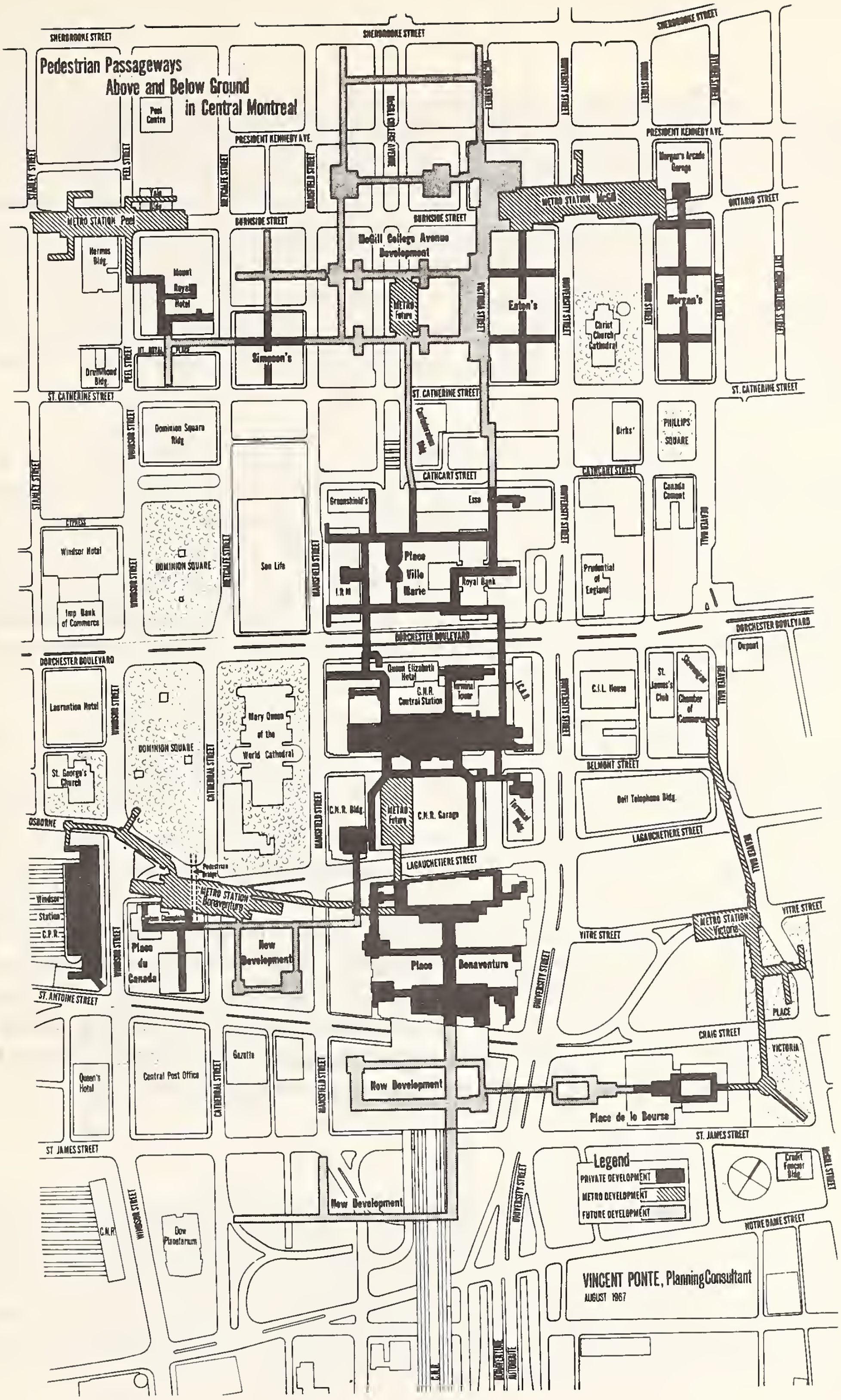


FIGURE A-2

PEDESTRIAN PASSAGEWAYS ABOVE AND BELOW GROUND IN CENTRAL MONTREAL sq. ft. of office space, 235,000 sq. ft. of retail space and parking for 1000 cars. Place Bonaventure includes a 400-room hotel, more than 100 stores, a 5-acre exhibition hall, and parking all within a total of 3.1 million square feet of space. The 1200-room Queen Elizabeth Hotel and the 620-room Chateau Champlain are connected. In total there are 2500 hotel rooms, 300 shops, and 50 restaurants.(6) Parking totals 3500 spaces.(2) The potential is still growing, and when surrounding trip generators which are adjacent to the system but not connected, are added, the potential for pedestrian trips becomes even greater.

The generators and attractors create the potential for pedestrian circulation, but it is the system itself that makes it happen. The Montreal system is almost entirely enclosed and climate-controlled, both summer and winter. Pedestrians can move within an environment designed entirely for them, over approximately forty acres without once being subjected to the intrusion of the automobile. In general, walkways are direct without serious discontinuities, comfortable, exciting, safe and secure.

If the system is deficient at all, it would be primarily attributable to its lack of visual contact with the surrounding city. In Place Ville-Marie, deliberate steps were taken to create contact with the outdoors by designing wells which physically and visually connect the below-grade walkways with a spacious exterior plaza. Despite this effort, the system does give the feeling of being underground and evokes the sense of confinement and disorientation that goes with the absence of the familiar outside contact. It has also been suggested that the system will develop to be too large and lose much of its pedestrian scale.(6) Finally, several problems resulting from the lack of an overall plan to guide developers -- both public and private -- have occurred; these are detailed in the next section.

A.1.3 System Elements

For all its obvious and praiseworthy success, the Montreal system, when viewed as a series of pathways, has distinct advantages and disadvantages. The system is basically a series of centroids, which may in themselves involve circulation, and a series of paths connecting the centroids. Each of the major pathways linking centroids of pedestrian activity is discussed below.

(1) West Passage between the CNR Central Station and Place Ville-Marie: This link is probably the most highly utilized section of the Montreal system. It is lined with diverse retail activity, is very direct and adequately provided with escalators to assist vertical movement. It stands in marked contrast to the parallel eastern leg which is described in (2) below. Daily pedestrian counts in winter have been recorded to be 60,000 to 90,000 pedestrian trips.(3) It connects two of the largest pedestrian generators in the system: the Place Ville-Marie encompassing 1.5 million square feet of office space, 50 stores totaling 235,000 square feet of retail space and 1000 parking spaces, and the railroad station attracting and generating tens of thousands of pedestrians per day; and it provides a connection directly to the 1200-room Queen Elizabeth Hotel. It provides pedestrians comfort and delight in a climate-controlled promenade, safety from the vehicle movement overhead on Dorchester Avenue which reaches 4,500 vehicles per hour during the evening peak,(4) and it provides protection from fumes and noise.

(2) East Passage between the CNR Central Station and Place Ville-Marie: This pathway stands in contrast to the west passage to PVM. The section within the station block is lined with railroad and communications offices and equipment. The entry to or exit from the east passage is located away from the center of activity within the station which tends to be west of center. On the other end, within Place Ville-Marie, a major discontinuity occurs when the pathway turns to the left rather than providing direct access into the Royal Bank Building, a major pedestrian generator and attractor. As a result of these attributes of poor directness and continuity and limited abutting activity, the east passageway counts have only been about 10-20% of those recorded on the western link.(3) Nevertheless,

the passage way does serveas an important link to the exchange of commuter trips shown in Table A-1.

TIME PERIOD	NUMBER OF PEDESTRIAN TRIPS		
	STATION TO PVM	PVM TO STATION	TOTAL
8:00 - 9:00 a.m.	5102	286	5388
10:00 - 11:00 a.m.	900	390	1290
11:00 - 12:00 a.m.	1143	716	1859
12:00 - 1:00 p.m.	2450	1901	4351
2:00 - 3:00 p.m.	1153	1149	2302
4:30 - 5:30 p.m.	1146	4290	5336

TABLE A-1

PEDESTRIAN COUNT - EAST PASSAGEWAY
CENTRAL STATION - PLACE VILLE-MARIE, MONTREAL

Source: Reference (4), Villemur, pg. 8.

(3) Walkway between the CNR Central Station and Place Bonaventure: This third passageway was in during the 1966-1967 construction of Place Bonaventure to connect under Lagauchetiere Street to the railway station. Place Bonaventure with 3.1 million square feet of space on six acres, a 400-room hotel, more than 100 stores and substantial parking space is a major pedestrian center. The walkway exhibits a high level of utilization due to the attraction of Place Bonaventure, but also due to its access to the Bonaventure Metro Station and development beyond. The walkway itself, however, shows the defects that often occur when new development is interfaced with existing structures. Leaving the CNR Central Station, the first stage of the walkway follows the perimeter of the CNR garage; a glass partition eliminates noise, weather and fumes, but the path-

way element shows the signs of a make-shift solution. The approach to Lagauchetiere Street is at-grade and the pedestrian can see an entrance to Place Bonaventure only about 60 feet away; the walkway, however, diverts to the right to a down escalator, then along a pleasant passage lined with shops to another escalator providing movement up to the main shopping level within Place Bonaventure. This vertical discontinuity acts as an impedance and results in numerous people dashing directly across Lagauchetiere Street without regard to safety or comfort. A more serious discontinuity occurs as a result of not having a direct connection to the Bonaventure Metro Station walkway. Instead, a pedestrian going from the CNR Central Station to the subway via the system must negotiate his way under Lagauchetiere up to Place Bonaventure, through its internal circulation system, and on to a different entry to the Metro. Although a knockout panel was provided,(3) it was apparently felt that the direct connection to the Metro in the extreme northwest corner of Place Bonaventure would short-circuit pedestrian movement away from the Place Bonaventure retailing. The walkway is used to influence the exposure to retailing. This same concept is used in the Minneapolis system where major access points to the second level pedestrian system are through department stores.

(4) The Partial East Link between the CNR Central Station and Place Bonaventure: This is a minor link in the system that is little utilized. From the exit of the CNR station, the walkway is covered but not enclosed. This is partially to allow taxi and passenger car pickups for people leaving the train station. A discontinuity occurs at Lagauchetiere Street where the walkway is interrupted. Very few people cross here, preferring instead the western route.

(5) Walkways between Place Bonaventure, the Bonaventure Metro Station, Place du Canada and Windsor Station: Access to the Bonaventure Metro Station from both the Windsor railway station and Place Bonaventure is via long, rather stark corridors. A substantial amount of vertical change is accomplished on both ends by escalators. These passages are obviously designed for the Metro associated commuter traffic and as such serve the purpose.

The interface between the subway station and the Chateau Champlain Hotel in Place du Canada further illustrates the inconguities between the private and public nature of the subsystem element. The connection was at first rejected and later introduced as an afterthought. As a result, to reach the hotel from the subway requires first an escalator trip, then a walk via a poorly marked corridor and finally an elevator which goes to the hotel lobby. Needless to say, this link is not utilized since only a few people know it exists. However, several comments by the Bonaventure station architect, Victor Prus, gives some insight into the relationship of the passages to the Montreal pedestrian system.(5)

> "The functions of a subway system do not vary greatly from those of the familiar surface street system.
>
> "In human experience, the various tunnels, stairs, bridges, platforms, etc., that constitute a subway station are related to the surface urban scene. In this sense, the station tunnel becomes a street--an extension of the surface street. Protected from rain and snow it is yet a hard sort of environment, subject to heavy wear and tear, subject to the considerable accumulation of dust and dirt, subject to considerable fluctuations in temperature, humidity and air currents. Here people are dressed as they are dressed in a surface street; here they wait for trains as they would wait for buses or taxis. Here there are crowds, accidental encounters, and unrelated individual purposes ... typical street scene.

> "To treat the environment as one would treat... an interior would result in an environment ...character which is incongruous with the... functions therein contained."

A. 1. 4 System Impacts

Like many successful pedestrian systems where the overwhelming acceptance by all parties negates the need or desire for after-the-fact impact studies, Montreal has not been well documented. By observation, the system obviously works. It teems with people day and night throughout the year, but actual measures of its impact on safety, congestion and the like are unavailable.

Pendakur, quoting a city traffic department source, has noted(6) that vehicular congestion and accidents involving pedestrians have been reduced as a direct result of the system. The system's impact on retailing is implicit in the fact that adjacent retail space has been fully renting as soon as it becomes available, and also that the established department stores to the north of the present core system are anxious to connect into it.(2) Retail space rentals are as high, if not higher, on properties abutting the system as those along the main shopping street(3) -- St. Catherine Street. Under certain conditions under street right-of-ways, the city establishes long term leasing agreements with private developers; rents and taxes are levied as a function of valuation of the public domain occupied. This gives rise to a net increase in rent and taxes on property that would not normally yield these revenues. A factor not to be overlooked as a substantial impact is that the system contributes in part to the overall stability of the downtown, and in this way provides the city with a broader, more secure tax base.(1)

A. 1. 5 Costs and Financing

The cost of the walkway system was borne mostly by the private developers and is not distinguishable from the total cost of development. When the magnitude of the investments is considered such as the $110 million for Place Ville-Marie and the $75 million for Place Bonaventure, it becomes a difficult task to separate those costs attributable to the pedestrian system, the truck circulation system, parking and so on.

As Ponte has pointed out,(1) the public development of the subways, and its stations and related walkways was largely made possible by the increased tax revenues generated by the private development of Place Ville-Marie. It is also interesting to note that further development of the pedestrian system into the financial administrative areas to the south and east of the present core will have to be paid for with public money since the major landowners in this area are the City and Province of Quebec.(6)

A. 1. 6 Locational Contingencies

Montreal is similar to many large-scale pedestrian systems in that it grew out of motivations and circumstances that had nothing at all to do with improvement or cost/benefit of pedestrian movement. The major factors that influenced the Montreal development are:

- unique existence of large land areas in the central urban core under single ownership;
- the contiguity of several of these areas;
- a decision to develop a unified plan involving cooperation between public and private interests;
- a lack of real competition from suburban development due primarily to a lag in individual mobility peculiar to Montreal;
- a climate that clearly influenced the need for an environment controlled system; and
- a topography that allowed a continuity of separated pedestrian movement at one dominant level (instead of two as is peculiar to most urban CBD's).

MONTREAL REFERENCES

(1) V. Ponte, "Man, Buildings, New Dimensions for Downtown," Skyscraper Management, December 1967.

(2) V. Ponte, "Montreal's Multi-Level Center," Traffic Engineering, September 1971.

(3) Interview with V. Ponte, October 30, 1973.

(4) J. Villemur, "The Montreal Downtown Pedestrian System," paper presented at the 50th Convention of the Canadian Good Roads Association, Edmonton, Alberta, Canada, September 1969.

(5) V. Prus, "Metro Architecture," (unknown source).

(6) V. S. Pendakur, "Pedestrian Circulation Systems in Canada," Highway Research Record, Number 355, 1971.

A.2 TORONTO

A.2.1 Background and Description

The needs of pedestrians in downtown Toronto have been the subject of recent civic concern since about the mid-sixties. City agencies responsible for planning and development recognized that Toronto was entering a period of active expansion and redevelopment in which large areas of the downtown would be rebuilt, and that the opportunity existed to provide a new pedestrian environment compatible with the needs of people who work and visit the central core. Earlier studies were consolidated and refined into a joint report(1) on pedestrian activity in downtown Toronto prepared by the Commissioner of Public Works, the city planner, the commissioner of development and the city solicitor, which was submitted to the Board of Control in May 1969. The report summarized the results of an evaluation of existing pedestrian circulation, defined future needs, proposed guidelines, estimated costs and discussed the implementation of a comprehensive system of pedestrian movement.

In May 1969, nearly all pedestrian movement in downtown Toronto was on the sidewalk system. The following deficiencies were noted:(1)

- overcrowding of sidewalks was impeding pedestrian movement in many areas at peak hours;
- many intersections were congested by people waiting to cross and waiting for buses, and by turning vehicles;
- vehicle flows restricted pedestrian crossing to intersections while many pedestrian desire lines occur at mid-block points;
- several access points to subways were congested at peak periods making movement difficult;
- danger of accidents due to conflicts with vehicles existed, discomfort of exhaust fumes were noted;
- extreme climatic conditions prevail over a large part of the year making walking difficult and unpleasant, alternative unexposed routes are few;

- a serious lack of open space and green areas, where open space does exist it is given over to auto parking;
- sidewalks lack a variety of distinctive places for the pedestrian; and
- many of the conditions cited above are tending to get worse, and the range and mixture of activities available to pedestrians is decreasing.

In recognition of these deficiencies, two programs were outlined.(1) The first involved improvements in the existing system by widening sidewalks, introducing one-way traffic, and introduction of crossing signals at selected mid-block locations. The second was a far-reaching program proposed to take advantage of the extensive redevelopment that was occurring, and to incorporate more fundamental solutions to the problem by providing a separate system of pedestrian circulation. A set of principles to serve as guidelines were proposed:(1)

- walkways through new and existing developments should be considered as alternatives and supplements to the existing sidewalk system;
- pedestrian movement between public and private space and between different private spaces should be integrated;
- continuity of the movement system is essential;
- climate control is desirable, but this does not imply a system totally excluded from the natural and city environments;
- open space should be deliberately and carefully planned in association with the system;
- walkways should provide a wide variety of activities and experiences, operating hours should at least coincide with operation of the public subway; and

- a high quality of design should be maintained with regard to services, signing, amenities, vertical movement and provision for the old and disabled.

The focus of the proposed development was to be along the north-south spline shown in Figure A-3. At the time of the proposal, the only existing elements of the system were the privately-developed below-grade pedestrian arcades in the Richmond-Adelaide and Toronto Dominion Centres. The first stage of development was to utilize and extend these existing components with an additional six links:(1)

- from the Civic (Nathan Phillips) Square across Queen Street to the Four Seasons Sheraton Hotel;
- from the Four Seasons Sheraton Hotel across Richmond Street to the Richmond-Adelaid Centre;
- from the Richmond-Adelaid Centre across both Adelaid and King Streets to the Toronto Dominion Centre;
- an eastern branch from the Toronto Dominion Centre under Bay Street and through the proposed development in the next block to the King Street subway station;
- from the Toronto Dominion Centre across Piper and Front Streets to Union Station (railway); and
- a western branch from the Toronto Dominion Centre across York Street to St. Andrews subway station.

The above proposals were approved, and the responsible agencies took action to coordinate and fund the specific connections. To date, a connection under Queen Street linking the Civic Square parking garage with a below-grade shopping mall within the Four Seasons Sheraton Hotel has been completed; the second link to the Richmond-Adelaid Centre under Richmond Street is also in. An overhead open pedestrian bridge has also been constructed at the second level to connect the Four Seasons Sheraton Hotel across Queen Street to an open elevated walkway around the perimeter of the Civic Square. Construction has started on components of the east-west branch,(2) and all other links are in various stages of discussion.

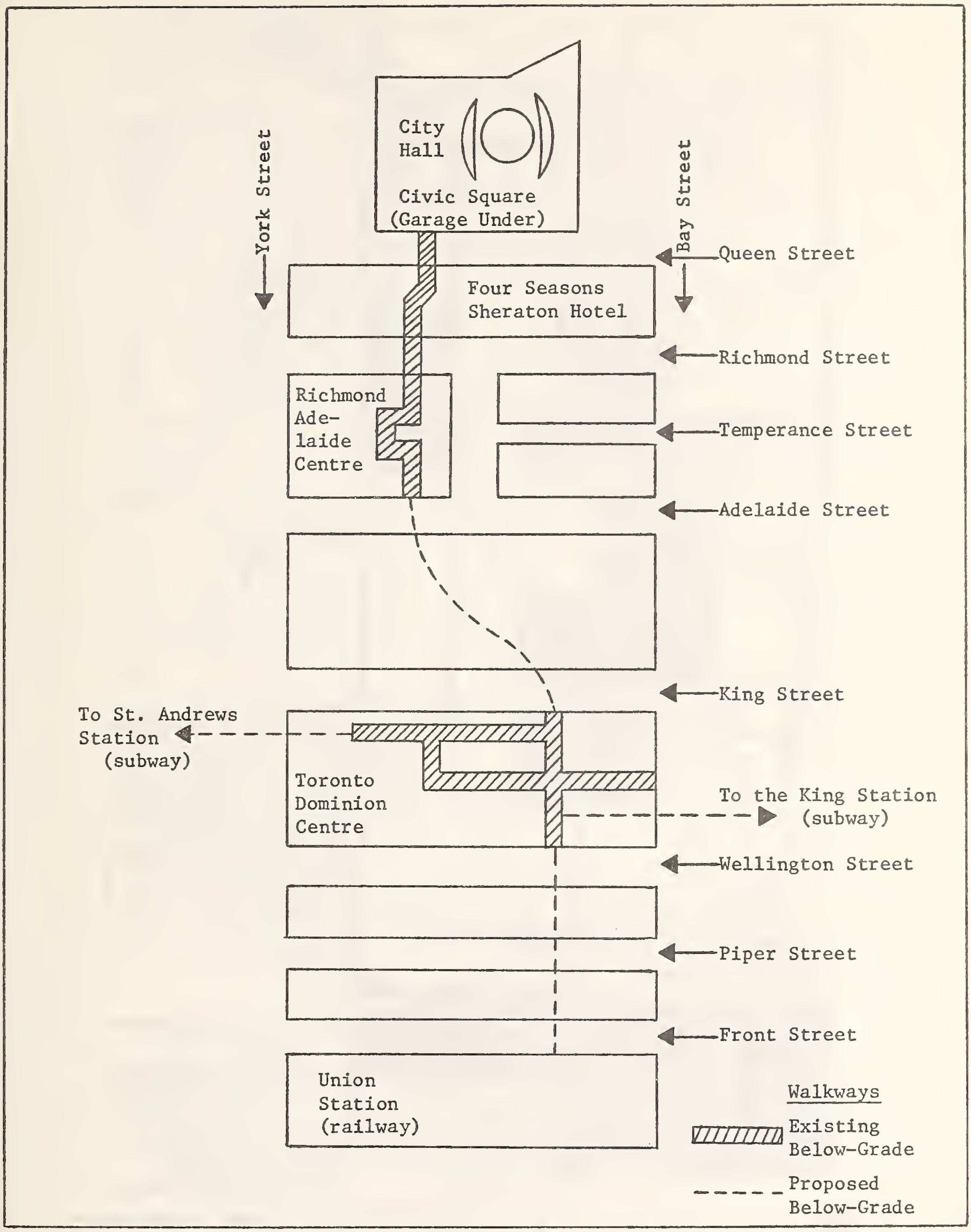


FIGURE A-3
MAIN NORTH-SOUTH SPLINE OF THE TORONTO PEDESTRIAN SYSTEM

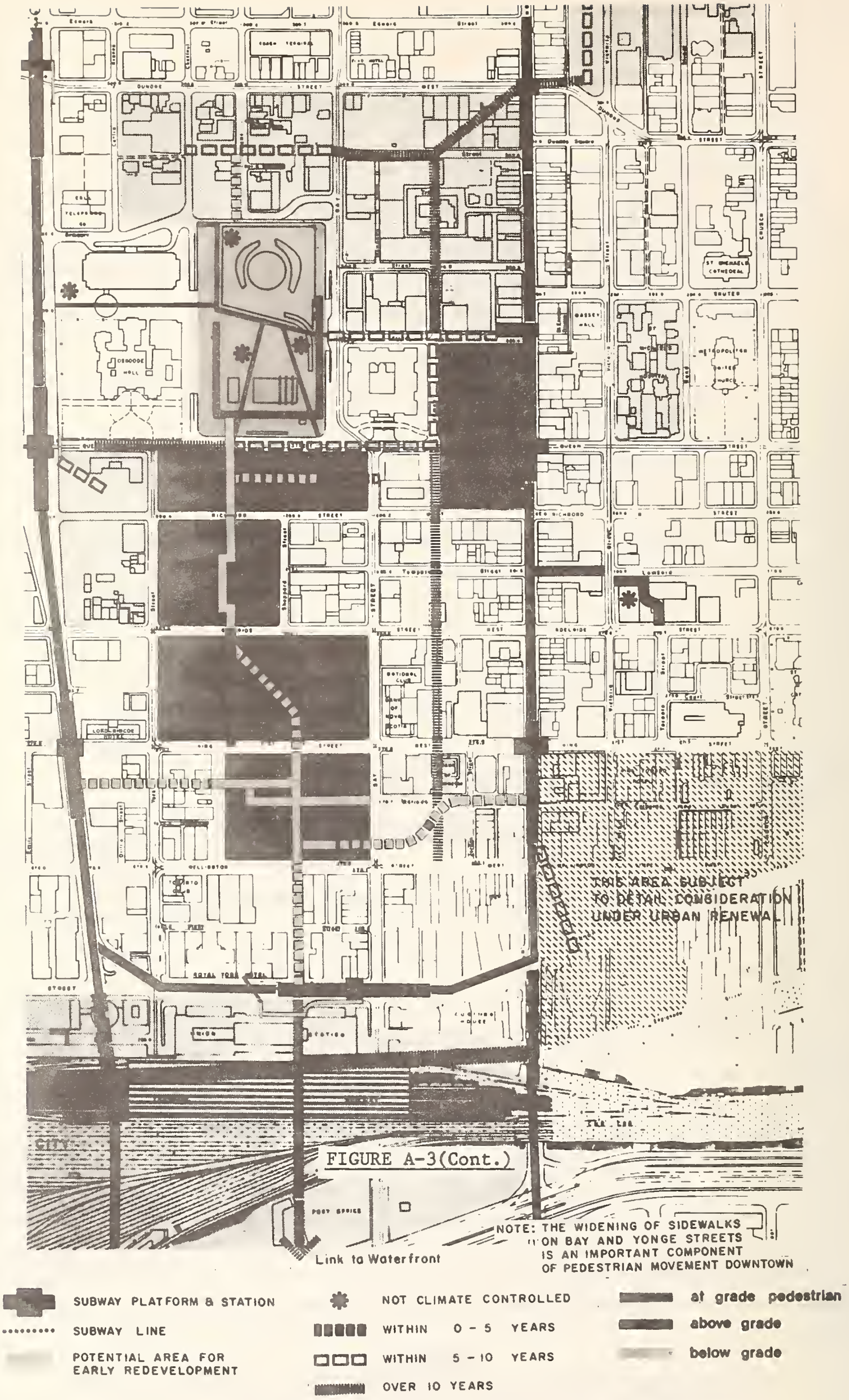
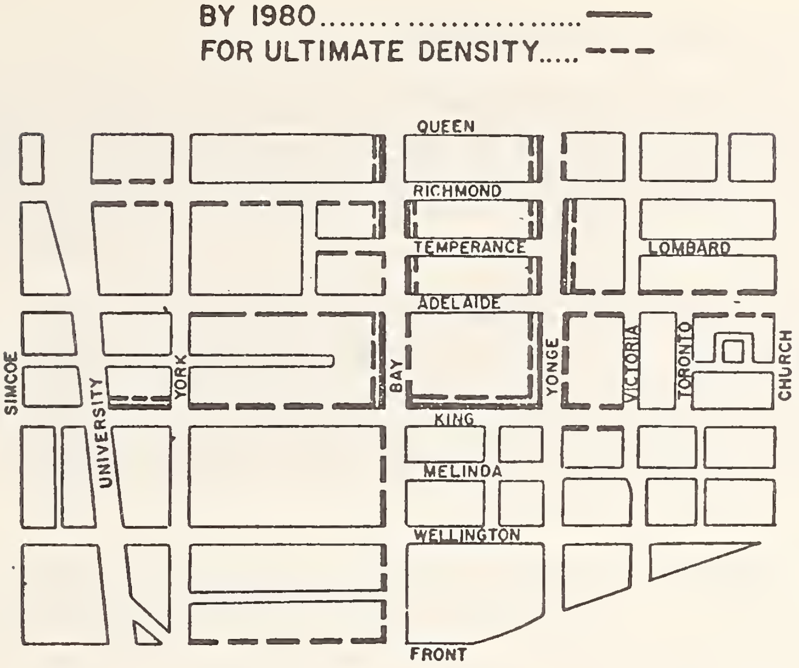


FIGURE A-3(Cont.)

THIS AREA SUBJECT TO DETAIL CONSIDERATION UNDER URBAN RENEWAL

NOTE: THE WIDENING OF SIDEWALKS ON BAY AND YONGE STREETS IS AN IMPORTANT COMPONENT OF PEDESTRIAN MOVEMENT DOWNTOWN

REQUIRED SIDEWALK WIDENING



REQUIRED CORNER IMPROVEMENTS

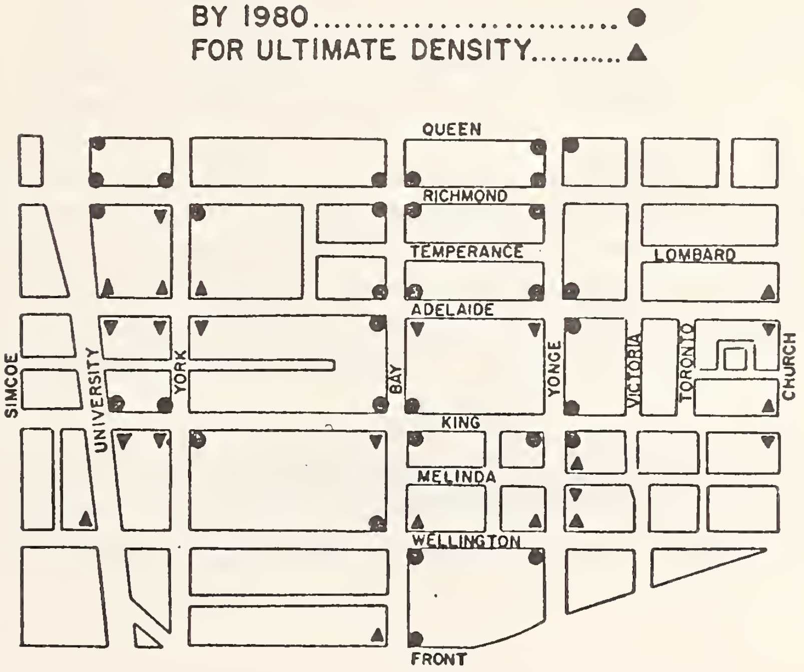


FIGURE A-3 (Cont.)

A.2.2 System Costs and Financing

The city has assumed that all intra-block development will be paid for by private investments, but is prepared to offer inducements. For the below-grade street crossings, the city has estimated the cost of twenty-foot wide walkways at between $1600 and $4500 per linear foot depending on the depth and number of utilities affected.(1) The utilities problem is significant; at one location there were two separate steam mains, three separate hydro-conduits, a gas main, a raw water main for fire protection, a domestic water main, a two-level telephone conduit, two separate telegraph conduits and a sewer. For the total of nine street crossings shown in the figure, two will be totally paid for by developers as explained below, and an estimate on the cost of the remaining seven is $1,460,000.

Estimates of the annual operating cost of each crossing are shown in Table A-2. It was recommended that the city seek the means to have the abutting property owners assume most of these costs.

SERVICE	ESTIMATED ANNUAL COST
Ventilation	$ 180
Heating	250
Air Conditioning	-
Lighting	270
Cleaning	1,800
Policing	-
Repair	1,500
TOTAL	$4,000

TABLE A-2

ESTIMATED ANNUAL OPERATION COST
TORONTO STREET CROSSINGS

Source: Reference (1), Joint Report, pg. 7.

The initial reaction of developers and owners to the pedestrian plan was one of reluctance due to uncertainties regarding overall participation of the city and other private entities, and the cost of this development. It was proposed that the city provide the leadership and participate directly in implementation of the plan. Several incentives have been proposed:(1)

- That the city, recognizing that the ultimate results will benefit both public and private interest, be prepared to finance up to 50% of the gross cost of construction (the city stood to realize in excess of $2,000,000 from the closing of streets and lanes and their conveyance to owners involved in the plan);

- That assessment or tax forgiveness be considered for private participants in the scheme;

- That a density bonus, as addition to the gross floor area allowed for development under existing zoning, be granted up to a limit of five square feet for each square foot of development within the context of the pedestrian system depending on size, construction cost, operation cost and location; and

- That exchange or sale of city owned lands, streets and interests where this would facilitate establishment of the pedestrian system (only those interests in way of the system) would be considered.

A variation of the last incentive was used to advantage in the development of the first two links connecting to the Four Seasons Hotel under Queen and Richmond Streets. The Four Seasons block was city-owned property, and the construction and maintenance of the connections were made mandatory requirements which developers had to take into account when submitting their bids for the property.(1)

General agreement has been reached with the developer of the block between Adelaide and King Streets(2) which when completed will connect the Richmond-Adelaid Centre with the Toronto Dominion Centre. It also appears that extension of the system south of that shown in Figure A-3, beyond what is now Union Station will be realized.(1) However, major links north and south of a proposed development, known as Metro Centre which will be built in the airspace over Union Station; are unsettled.(2) Metro Centre with an expected 20,000 residents and 40,000 office workers will act as a major bus, subway and railway terminal,(2) and will be an extremely important trip generator upon which the success of the entire north-south spline may depend.

TORONTO REFERENCES

(1) Joint Report, "On Foot Downtown," prepared jointly by the Toronto Commissioner of Public Works, the Chief Planner, the Commissioner of Development and the City Solicitor, Revised February 1973.

(2) V. S. Pendakur, "Pedestrian Circulation Systems in Canada", Highway Research Record, Number 355, 1971, pp. 54-68.

A.3 MINNEAPOLIS

A.3.1 Introduction and Description of the System

The Minneapolis Pedestrian System actually consists of two semi-independent systems of entirely different nature. The Nicollet Mall is a totally reconstructed eight-block section of street, radically redesigned to be shared primarily by pedestrians, transit and occasionally by taxis and other special-purpose vehicles.

These vehicles move on a two-lane serpentine "transit-way." The rest of the right-of-way is devoted to pedestrian movement, to handsome landscaping, and to special facilities like heated bus shelters and a self-service post office.

The unique midblock skyway system, the second system, provices protection from the harsh Minnesota winters and has encouraged considerable development of second level retail arcades. Because of the different nature of these two systems and their separate geographies, each is described individually below. A plan of the two facilities is shown in Figure A-4.

A. Nicollet Mall

The Nicollet Mall in Minneapolis has been described in many ways: from "elegant and urbane" to simply "one of the nicest places to be downtown."

Such descriptions usually reflect the visual reaction of any one of the shoppers, workers, and visitors who come to Minneapolis' prime retail district and find it a new and exciting downtown shopping environment. Everything is designed to say, "This is the city, alive and well," a dynamic urban place and all that that term implies. Nicollet Mall is much more than meets the eye. Literally, this is true, for of the $3.8 million cost, only $1.3 million was for above ground improvements. The undertaking of the magnitude of this major downtown Mall was quite complicated and has taken cooperation of many private business interests and public agencies and services, joined in a common desire to do something substantial for the community. Achieving the necessary consensus and cooperation of all necessarily involved parties is as important as the design concept facility, as the design and implementation itself. The eleven-year effort of local business and governmental officials to create the Mall was treated as part of a comprehensive planning and programming

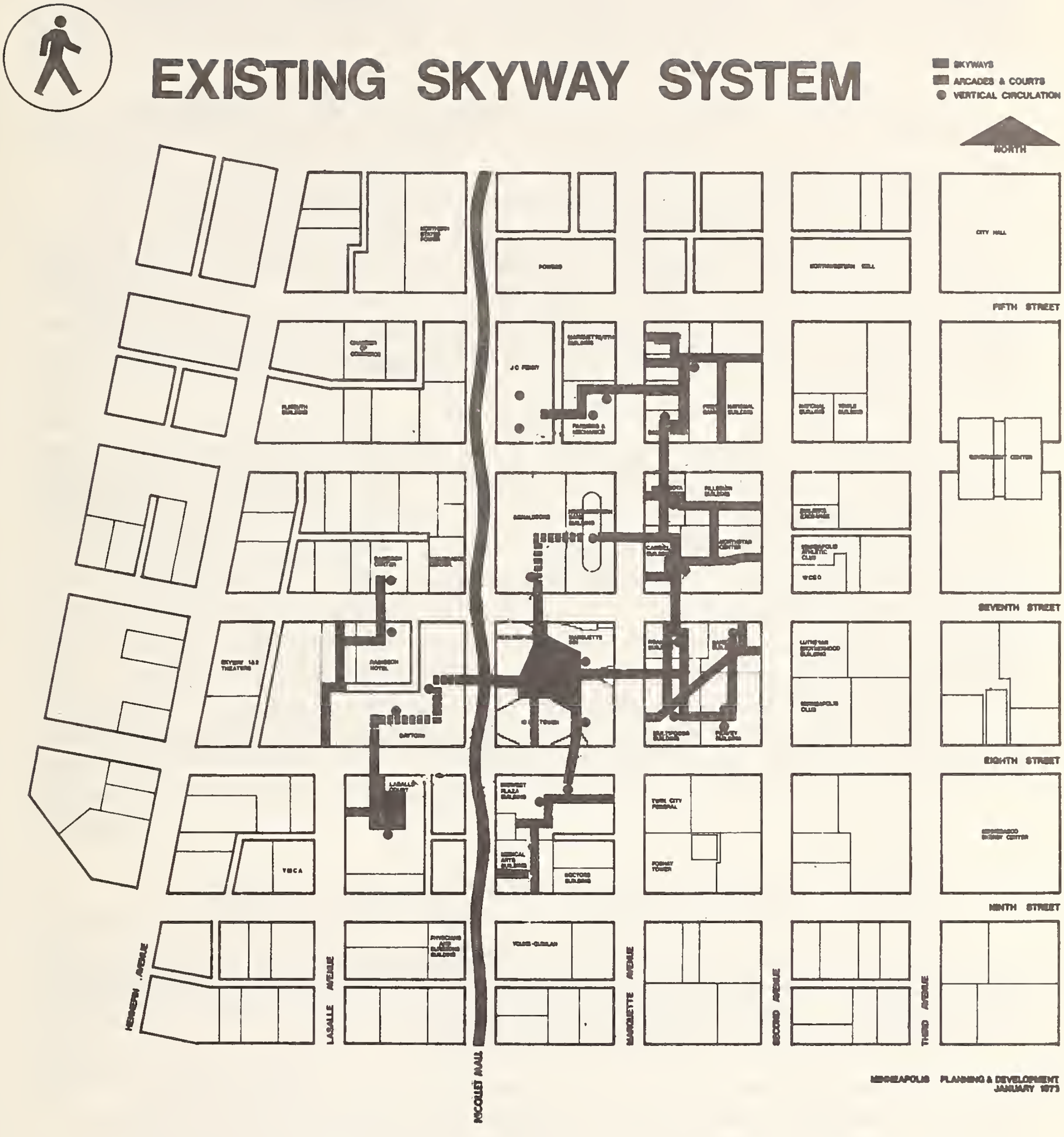

EXISTING SKYWAY SYSTEM
SKYWAYS
ARCADES & COURTS
VERTICAL CIRCULATION
NORTH
CITY HALL
POWERS
GOVERNMENT CENTER
J C PENNY
FARMERS & MECHANICS
CHAMBER OF COMMERCE
DONALDSONS
PILLSBURY BUILDING
NORTHSTAR CENTER
MINNEAPOLIS ATHLETIC CLUB
WCCO
SKYWAY 1&2 THEATERS
RADISSON HOTEL
MARQUETTE INN
DAYTON
IDS TOWER
LUTHERAN BROTHERHOOD BUILDING
MINNEAPOLIS CLUB
LASALLE COURT
MIDWEST PLAZA BUILDING
MEDICAL ARTS BUILDING
DOCTORS BUILDING
YMCA
TWIN CITY FEDERAL
FOSHAY TOWER
PHYSICIANS AND SURGEONS BUILDING
FIFTH STREET
SEVENTH STREET
EIGHTH STREET
NINTH STREET
HENNEPIN AVENUE
LASALLE AVENUE
NICOLLET MALL
MARQUETTE AVENUE
SECOND AVENUE
THIRD AVENUE
MINNEAPOLIS PLANNING & DEVELOPMENT
JANUARY 1973

FIGURE A-4

effort, not as an isolated project. The Nicollet Mall development process, in fact, added considerably to the strength of the overall planning process in Minneapolis.

The Mall resulted from a combination of strong leadership and attention to political detail and the realization that the first step in civic improvements is the difficult one of setting policy and obtaining agreement in principle. The persistence and patience of those who saw the project through from the late 1950's to its dedication in 1967 finally overcame the incredible technical and administrative obstacles; there are no shortcuts to plan acceptance. Further, the Mall today does not just exist; it is maintained and enhanced through continuing effort and this is paid for through annual special assessments on the affected property.

A report entitled, "Nicollet Avenue Study: Principles and Techniques for Retail Street Improvement," was published in 1960 and concluded that major improvement was both possible and desirable. A caveat was included that the improvement conform to guides set forth in the planning commission's concurrent work on an overall "Central Minneapolis Plan." These guidelines dealt mainly with the need for emphasizing pedestrian movement, for relating Nicollet improvements to other elements of Central Minneapolis, and for maintaining sound patterns of traffic and transit movement. The city plan called for Nicollet to be a "specialized street" for retail uses serving the metropolitan area and region.

Planning

Specific planning objectives were set forth as being:

(1) to improve pedestrian circulation in terms of efficiency (adding capacity to walking routes) and comfort (minimizing hazards and creating a more pleasing environment);

(2) to improve access and encourage mass transportation usage, by making transit more attractive, by relocating bus lines to provide more direct service to the retail area, by creating good pedestrian access to parking facilities, and by generally reducing traffic congestion;

(3) to create new opportunities for promotion of the retail area and the Central Business District, by building upon the image of

Nicollet Avenue as the prime retail center of the Upper Midwest and by strengthening this identity by adding new attractiveness in terms of beauty, excitement, and interesting features; and

(4) to encourage private investment by creating a stable environment for retail business and other central area commercial activity.

The transitway scheme was accepted early because of its potential for linking the retail area with every Minneapolis neighborhood by bus. Although the idea of the transitway had become firmly established early, some still question the validity of the decision to retain transit rather than giving over the full right-of-way to pedestrian use. The transitway has not been the great incentive to use transit that some had expected. The original rationale was nonetheless clear, and there is little reason now to doubt this policy decision. Pragmatically, the justification for the transit lanes was, and is, that the prime retail center is directly linked by transit to every Minneapolis neighborhood. Indeed, every downtown bus route, but one, either crosses the Mall, operates on it, or runs parallel to the Mall only one block away. The city's planners placed additional, but more abstract, value upon the transit facilities. Symbolically, the concept was designed to give transit a more important place in the total scheme of downtown at a time when public transportation was of much less concern than it is today. The Mall dramatizes this importance to the community and offers the shopper a genuine choice of modes. It is especially noteworthy that a new Minibus system has been put into operation in downtown Minneapolis, with the Mall the backbone of its routing.

In design terms, the serpentine nature of the transitway also became a key element of the early conceptual decision. Rather than prescribing a straightaway alignment, planners and traffic engineers collaborated in developing the idea that a gentle undulation of the transit lanes could create variety, make possible larger and more interesting open spaces within the curvatures and visually reduce the linearity of the Mall.

Financing

The problem of financing likewise demanded new and creative approaches. Hundreds of hours were spent by local officials, the planners and engineers, and downtown representatives working out and testing a complex formula for assessing the costs on an equitable basis. The Mall was widely considered to be of benefit beyond its own frontage, and this is attested to by the final assessment scheme which allocated to frontage owners more than half of the total assessment while properties off the Mall bore the remainder. The plan included two benefit zones -- on the Mall and off the Mall -- covering some 18 blocks, with each zone having sectors providing for 100%, 100-75%, 75-50%, and 50% allocation of cost so that properties closest to the center of the Mall would bear the greatest proportion of both construction and maintenance expense.

After the assessment formula was accepted, two then-new federal aid programs whose application to malls were essentially untested were also incorporated into the plan. An Urban Mass Transportation Demonstration Grant was negotiated in the sum of $512,500. An Urban Beautification Grant of $483,500 was sought and secured, but in this case federal procedures required the onerous task of composing a city-wide beautification application at a point when no guidelines had been established. The ultimate mall cost of $3,873,904.22 was thus covered by a combination of the local assessments and the federal assistance.

Design

The landscape design is characterized by both variety, in which each block was planned to have its own special character, and unification, achieved through the unique lighting system and design of street furniture, paving and structural features (bus shelters, benches and signing, etc.) which were used throughout its length. Virtually every surface detail of the Mall was designed anew.

Features in the plazas include heated bus shelters, six fountains (some with heating coils to extend the useful season, one of free form graphite sculpture, and all using subdued lighting in their water display), flag poles, a 17-foot high four-faced clock with a mobile, four directories of store locations and a recording weather station.

Lighting is urban in character, providing sparkle, with pools of light and darker areas rather than conventional uniform brilliance. Lighting intensities were carefully conceived to give due prominence to window displays. Light standards are of pedestrian scale containing low-watt clear bulbs in clear housings and delineating the curvilinearity of the transitway. Fountains, planters, and tree grates are uniquely lighted.

Street furniture and accessories are specially designed and placement is rigidly controlled. This includes trash containers, bollards, benches, planters and bronze anodized aluminum traffic signal housings with integrated street name signs and traffic instructions. Police and fire call boxes, mail boxes, signal controllers, and similar furniture have been relocated to appropriate places on side streets.

Overhanging store signs have been removed by ordinance. Sidewalks have built-in snow melting capability, as befits a heavy snowfall area.

Plantings are largely in raised containers or under grates, with seasonal floral arrangements in pots and planters. All trees can be removed and replaced as necessary through removable base covers. A complete water system is installed for maintenance of plants and trees and for housekeeping.

Color is used sparingly and in subdued natural tones. Bright colors are introduced in the seasonal banner and floral displays, in some lighting, and at the postal station. Sidewalks are of rustic terrazzo in earth tones, accented by bands of antique tile reflecting basic elements of adjacent structures. The crosswalks are also of terrazzo. Various inlaid materials demark special areas, and medallions mark the intersecting streets. Native Minnesota granite in various colors is used in the bus shelters, for bollards, as copings, for drinking fountains, and in the flagpole and clock bases.

Utilities

Virtually the entire space under the 80-foot right-of-way is occupied by utilities: main power transmission equipment of the Northern States Power Company, Northwestern Bell's trunk telephone lines, a system of mains of the Minneapolis Gas Company, Western Union ducts, two major water mains and three sewer lines. Each of these has service connections into various buildings fronting the street. This posed two problems requiring both engineering design skill and negotiation and collaboration among the utility agencies. First, the configuration of the utilities and their need for access became a determining factor in arrangement of surface facilities and special features; and, second, if the Mall were to remain as undisturbed as possible over time, all underground systems would have to be placed in prime condition.

The private companies agreed to inspect their systems and rework them as necessary, with the understanding that street openings in future years would be held to a minimum. The city decided to undertake extensive replacement and reconnection of water services and other city facilities. Other intricate work was required to provide for relocation of fire hydrants and for treatment of electric circuitry. Ultimately, the design required a completely new system of modern traffic signalization.

Many of the buildings fronting on Nicollet Avenue had basement areas that projected out under the street right-of-way. These required extensive reworking, with the existent load-bearing walls becoming key factors in surface design. Space had to be found underground to accommodate auxiliary equipment necessary for the operation of fountains, drinking water coolers and plant irrigation systems. Drainage structures were doubled, and new elevations for the street with its transit lanes and mall treatment had to be established. Countless other engineering problems, large and small had to be faced, with even minor ones talking on major proportions for the affected property owners and calling for continuous cooperation between owners, designers and cost-conscious officials.

Because of extremely confined relationships between underground conditions and the desired surface arrangements, plans had to be developed on the basis of construction sequence: first, underground utilities and services; second, areaways; third, foundations, curbs and gutters; fourth, general electrical work and traffic signals; fifth, dimensioning of concrete slabs and types of joints; sixth, snow melting mats; and seventh, placement of special above-ground features, paving and planting materials.

B. Skyways

Lack of protection from the rigorous Minnesota climate, vehicular-pedestrian conflict, and air pollution are the three major problems affecting pedestrian circulation in downtown Minneapolis which resulted in the desire to provide an enclosed pedestrian skyway system.

The first two pedestrian skyways were built in 1962 as part of the Northstar Center, connecting this building across Seventh Street to the Roanoke Building, and across Marquette Avenue to the Northwestern Bank Building. Since that time, eight additional skyways have been built. At least five more are programmed as part of present construction, and a minimum of four more are in the planning stage. Private funds are being used for construction of the skyways. The skyway and arcade system has increased the rental receipts of space on the second level of the connecting buildings significantly so that the second level rental rates are now approximately the same as rates on the first floor, without lowering first floor values ($20/sq. ft. -- about the same as shops in an enclosed retail shopping mall).

The four newest skyways were built as part of the IDS Center by IDS Properties, a major developer headquartered in Minneapolis. The IDS Center was designed to be the nucleus of the skyway system and Nicollet Mall, which passes by one side of the tower building in the complex.

The success of these skyways and their increase in numbers clearly indicates their desirability in downtown Minneapolis. Even though the system is not entirely interconnected, use is quite high, with one of the first pedestrian bridges averaging about 7,000 persons on a typical summer's day, and increasing to 18,000 persons a day during winter. When skyways connect the new fringe parking ramps in the periphery of downtown, an estimated 40,000 people will travel over one of these new routes during a typical winter's day.

Although the distances that most people walk in downtown are not great, the usual pedestrian environment gives them little or no protection from either air pollution or severe winter weather. The conflict between pedestrian and automobile also impedes the movement of both. The lack of protection in bad weather not only increases the discomfort of pedestrians but has an adverse effect on downtown business.

Vehicular traffic has become extremely congested in the downtown core. In order to help alleviate some of this congestion, large parking facilities will be constructed in the periphery of the core, with direct access ramps to freeways or major arterials so that automobiles will not have to use local streets. The fringe parking concept will not be successful unless the pedestrian is comfortably accommodated from his car to his downtown destination. This calls for a completely interconnected skyway and arcade system which will connect the fringe parking facilities with the city core. At present, the average walking distance from automobile parking to work is 900 feet in the core area, and most of this distance is now travelled at street level. The average distance from fringe parking ramps would be about the same or less, with the added convenience of walking in climate-controlled comfort.

Skyway connections from offices and fringe parking ramps to the heart of the retail area should further increase the value of buildings. Direct and convenient access from core parking to the retail area should also bring in increasing numbers of customers. Both large and small businesses can benefit from the system since, if built as planned, the skyway plan for Minneapolis would connect a total of 64 blocks in the core of the downtown with a second level climate-controlled pedestrian system. The proposed system would be connected by 76 skyways, of which 15 are either currently in place or programmed to be constructed in the immediate future.

The Minneapolis Skyway Plan - Systems Description

The skyway plan consists primarily of mid-block crossings which will connect with arcades through buildings to form one continuous system. The skyways will also connect with a series of enclosed courts which can create a sense of place, and provide beauty, comfort, and year-round activities. Some of the courts would rise several stories and be accessible from both the skyway and street levels. In order to carry out this plan, changes in the zoning law would require new downtown developments to incorporate skyways into their buildings. Benefit assessments will be used to finance the remainder of the skyways and arcades through existing structures, as well as provide for maintenance.

When completed in 1985, the skyway system will be concentrated around two primary lines which run generally north-south and east-west. Feeder lines will be added to connect the rest of the area. The east-west primary line will provide direct access from the fringe parking along the Third Avenue N. distributor through the entertainment, retail, and office districts to the Civic Center, General Hospital, and more fringe parking on the eastern boundary of downtown. The north-south line will run from Gateway Center to the auditorium and parking on the south, and will pass through retail activities, the office core, and the hotel district.

Description - Systems Characteristics

1. Dimensions: Each skyway is 20 feet wide, approximately 20 feet in height, and 80 to 140 feet in length.

2. Structural: The skyways extending from the main track at the IDS Crystal Court are a continuation of the IDS Center's structural system. This is a three-dimensional steel truss, with the roof of the skyway acting as the main spanning member and the floor and sides of the skyway being suspended from this main truss. Clear span dimensions range from 80 to 140 feet unsupported.

3. Enclosure System: Each skyway is fully enclosed by a glass panel and steel mullion skin. The system is fully air conditioned and heated. The mechanical systems are located in a continuous channel running along the lower portion of the pathway. The enclosure system also makes provision for fully integrated interior and exterior street lighting. All mechanical and electrical systems utilize the central utility systems located in the IDS Center (that is to say that all systems are supplied from the IDS Central Plant rather than operating from independent systems in the skyway itself).

Staging and Financing Program

A staging program for skyway construction has been developed. Basically, the order of priority was constrained by the projected dates for completion of the various fringe parking ramps, and attempts to complete the two primary lines at the earliest possible date.

All of the existing skyways and those programmed for construction have been financed privately. Current costs for a bridge spanning the street run in the vicinity of $300,000, depending upon the design and the problems incurred by differences in floor elevation between connected buildings. Renovations of building interiors to accommodate arcades have been costing upwards of $150,000. Of course, the incremental cost of arcades designed as part of new buildings is much less.

Minneapolis will not be able to rely entirely on private funds if it is to continue to expand the skyway network. Many of the projected skyways connect buildings whose owners will not be able to finance the venture independently. Although there are several ways of financing these additions to the system, the most likely will be the creation of a benefit assessment district. The city would initially pay for the system, but the properties benefiting from the installation would be assessed at a higher rate, depending upon the amount of skyway and arcade frontage and benefit derived. This extra tax money can then be used to reimburse the city for its capital expenditure. The Nicollet Mall has been financed in this manner and has proven to be quite successful. The benefit assessment is figured over a 20-year period, after which taxes return to their normal rate.

Minneapolis Skyway System - Phasing through 1974

Development Phase No.	Year	Element
Phase 1	1962	Cargill - Northwestern Bank
Phase 2	1962	Cargill - Roanoke Building
Phase 2-1/2	1962-69	Farmers & Mechanics - J.C. Penney
Phase 3	1970	Dain Tower - Farmers & Mechanics Dain Tower - Minnesota Federal Radisson Center - Radisson Hotel LaSalle Court - Daytons
Phase 4	1973	Donaldsons - IDS Daytons - IDS Roanoke Building - IDS Midwest Plaza Building - IDS
Phase 5	1974	Baker - Twin City Federal

A. 3. 2 Systems Costs

A. Skyways

1. Inventory

The following table provides the costs of the four major skyways which extend from the IDS Center into adjacent blocks.

Inventory of Skyway Costs*

Name of Skyway	Length in Feet	Total Cost	Cost/ sq. ft. *
Dayton Skyway	140	$375,800*	$134.00
Donaldson	110	291,400	132.00
Baker	130	392,500	151.00
Mid-West Federal	130	298,500	115.00
Avg = $133.00 per sq. ft.			

* May 1973 figures from interview with H. Swanson
Construction Director for IDS Properties
FNC WINN

2. Correlation of Minneapolis Skyway Costs to Cost Estimating Factors

The average square foot cost of the Minneapolis skyways is $133.00/sq. ft. In order to compare this cost with the estimated base construction cost in Chapter 3, we must adjust the square foot cost to both a temporal index as well as the inflation curve. Since the Minneapolis figures are current (1973), there is no adjustment for inflation. However, the geographic adjustment factor for Minneapolis, Minnesota, is 0.99 or

133 x 0.99 = $131.67/sq. ft. (cost used for comparison).

This square foot figure is $37 sq. ft. below the estimated base cost for similar construction. The cost savings are principally a function of the following locational conditions.

3. Cost Savings and Contributing Factors

The superstructure of each skyway is an extension of the structural system of the IDS. It is merely a continuation of the structural members employed in the IDS facility. This results in simplifying structural and support connections and reducing construction time.

The skyways were constructed at the same time that the IDS Center was built. This resulted in construction as well as operational cost savings.

The skyway system utilizes all mechanical and electrical systems of the IDS Central Plant, thereby borrowing all support systems from IDS. This is estimated to reduce the square foot cost for mechanical systems by one half. That is to say, the cost of mechanical systems in a facility similar to IDS would average about $12-13/sq. ft., as compared to the cost of providing separate independent mechanical systems for each skyway, which can run anywhere from $25-30/sq. ft. Operating from a central plant is quite adequate in cases where there is no conflict between public and privately owned and operated space. In Minneapolis all skyways are private thus far, making central plant operation feasible.

Specific quality and quantity of sub-elements such as floor covering, light spacing and the materials employed in the enclosure system are other factors contributing to cost savings. However, the impacts of these are difficult to measure.

Connecting the skyways directly to adjacent facilities contributes additional cost. In Minneapolis the cost for additional support structure contiguous with existing facilities ranges from $36-45,000. This can be compared with the cost of pier construction of $3,960 where a pier is not located directly abutting an existing facility.

In addition, extensive modification and alteration to existing building facades were required in the buildings on the ends of the skyways extending outward from the IDS court. This cost has run approximately $3,000/ln. ft. of renovation, or approximately $150,000 to build the facades.

4. Operation and Maintenance Costs

Since the skyways are privately owned they are not operated and maintained by the city. IDS time studies show that maintenance on skyways averages 1/2 man-hour/sq. ft. /year, or each 4,000 sq. ft. requires one man-year ($150/sq. ft. maintenance).

B. Mall Costs

1. Construction Costs of Nicollet Mall

The following table provides the initial construction costs of the 10-block mall.

Item	Cost		Total Cost
	Above-Grade	Below-Grade	
Landscaping	$ 116,609	$ 0	$ 116,609
Street Furniture	433,475	0	433,475
Electric/Lighting	329,026	792,304	1,121,330
Mechanical Services	0	1,707,696	1,707,696
General Surfacing & Finishing	420,890	0	420,890
	$1,300,000	$2,500,000	$3,800,000

2. Correlation of Mall Costs to Cost Estimating Factors

The average construction cost per block for the Nicollet Mall is $380,000. However, this figure includes a substantial amount of expenditures related to utilities replacement and upgrading not included in the Base Cost Formula in Chapter 3. In order to compare the minimum Mall costs to the base cost estimates, the utility costs must be subtracted. The utility costs were $2.5 million of the $3.8 million expenditure or $1.3 million (comparative cost). Thus the cost per block for the Mall itself is:

$$\frac{1,300,000}{10 \text{ blocks}} = \text{\$130,000 average cost for a one-block area } 80' \times 320' \text{ or } 25,600 \text{ square feet.}$$

To compare this figure to the average estimated base cost, it must be adjusted by use of the geographic index for Minneapolis which is 0.99:

$130,000 x 0.99 = $128,700 cost adjusted for comparison

The base cost estimate for similar construction of what could be considered a partial mall is $119,700 per block plus $31,250 for transitway improvements or $150,950 per block total. Thus, the Minneapolis costs are $22,250 less than the base estimated cost. This is principally attributable to the following conditions:

- Smaller quantity of Mall elements - in Minneapolis specifically less trees per block, less seating area, the absence of planting and ground cover, and less employment of street furniture.
- Different qualities of materials employed for the construction of various Mall elements, compared to those assumed in the base cost estimating procedure.

3. Maintenance and Operating Costs

Table A-3 gives a breakdown of the maintenance and operating costs for Nicollet Mall as experienced in 1971 and budgeted for 1973, and the procedure used to arrive at the total annual assessment to be distributed to the participants in the Mall.

A.3.3 Skyway Systems Utilization

Minneapolis has been conducting extensive pedestrian counts in its CBD since about 1944. Of particular interest are those in recent years which include counts of pedestrian utilization of the skyway system. In general, the pedestrian counts are taken twice during each year; the first is conducted during June and July, and the second is made in December during the pre-Christmas period. The summer program covers approximately 60 to 70 stations; the winter counts include only 10 to 15 stations, restricted primarily to the skyways and a few other selected points, such as building entrances.

While the Minneapolis pedestrian data collection program represents the most extensive continuing effort found, the way in which the data are collected gives rise to numerous problems for

	1971 Actual Expenditures	1973 Proposed Budget
LABOR		
Sweeping and Cleaning	$ 35,056	$ 42,838
Snow Removal	6,945	8,359
Planting and Plant Maintenance	15,751	19,852
Maint. and Repair of Structure	7,766	9,404
Fixture and Glass Maintenance	19,524	24,032
Subtotal Labor	$ 85,042	$104,485
OTHER THAN PERSONAL SERVICE		
Repair of Street and Crosswalks	4,028	10,250
Repair of Sidewalks	9,092	21,730
Sweeping and Cleaning	12,518	11,478
Snow Removal	1,970	4,018
Mechanical Equip. Repair and Maint.	13,622	16,400
Music Rental Service	1,230	1,230
Planting and Plant Maintenance	27,490	33,954
Tree and Shrub Replacement	0	1,025
Maintenance and Repair of Structures	22,078	21,381
Christmas Lighting and Decorations	0	20,500
Electricity Power Cost	62,484	69,899
Lamp Replacement	2,208	2,306
Fixture and Glass Maintenance	5,896	9,811
Street Light Maintenance	1,717	6,663
Personal Injury Awards	1,928	2,050
Subtotal Other	$166,261	$232,695
TOTAL	$251,303	$337,180
1971 unexpended app. trans. to 1972		(35,237)
Increase required for 1972 Budget		$ 33,069
Credit cost normally spent by City on Nicollet Avenue		$336,012
Street Maintenance Tax and Assessment credit		$ 44,100
Amount to be assessed for in 1973		$290,912

TABLE A-3

MAINTENANCE AND OPERATING COSTS - NICOLLET MALL analysis of the pedestrian system utilization. It should be noted that analyses of this type are not the primary purpose of these counts, and that constraints on resources determine the methods used for collection. However, the following points are noted to provide a background for understanding the results obtained:

- the winter counts are obviously affected by both the severe climatic conditions in Minneapolis in December and the onset of Christmas shopping; it is not possible to distinguish these two effects using these data;
- the summer count is conducted for different stations on different days, thereby introducing the potential for a day-of-week or weather condition bias; while these effects can be isolated to a limited extent, the proliferation of different conditions complicates analysis and precludes definitive conclusions; and
- the direction of movement at the sidewalk level is perpendicular to that occurring on the skyways above; hence, direct comparison of volumes is complicated by the difference in movement patterns.

Notwithstanding these difficulties, the Minneapolis pedestrian counts do reveal some interesting patterns. For example, Figure A-5 shows the distinct seasonal trend for skyway utilization. The seasonal effect, using 1970 data, is further detailed in Table A-4. Note that while the total volumes had increased substantially from summer to winter (December), the skyways show the greater change. This illustrates the comfort aspect of enclosed pedestrian systems. Where the volume had increased, most of it was transferred inside to paths designed primarily for pedestrian circulation.

A second example of attraction to the skyways for comfort reasons is shown in Figure A-6. Here the transfer is due largely to inclement weather. The impact might have been even greater if the hot, humid day had instead been more pleasant. Further, analysis conducted by Minneapolis shows that Friday volumes were, in general, larger than Tuesday volumes which would have increased the effect of weather even more.

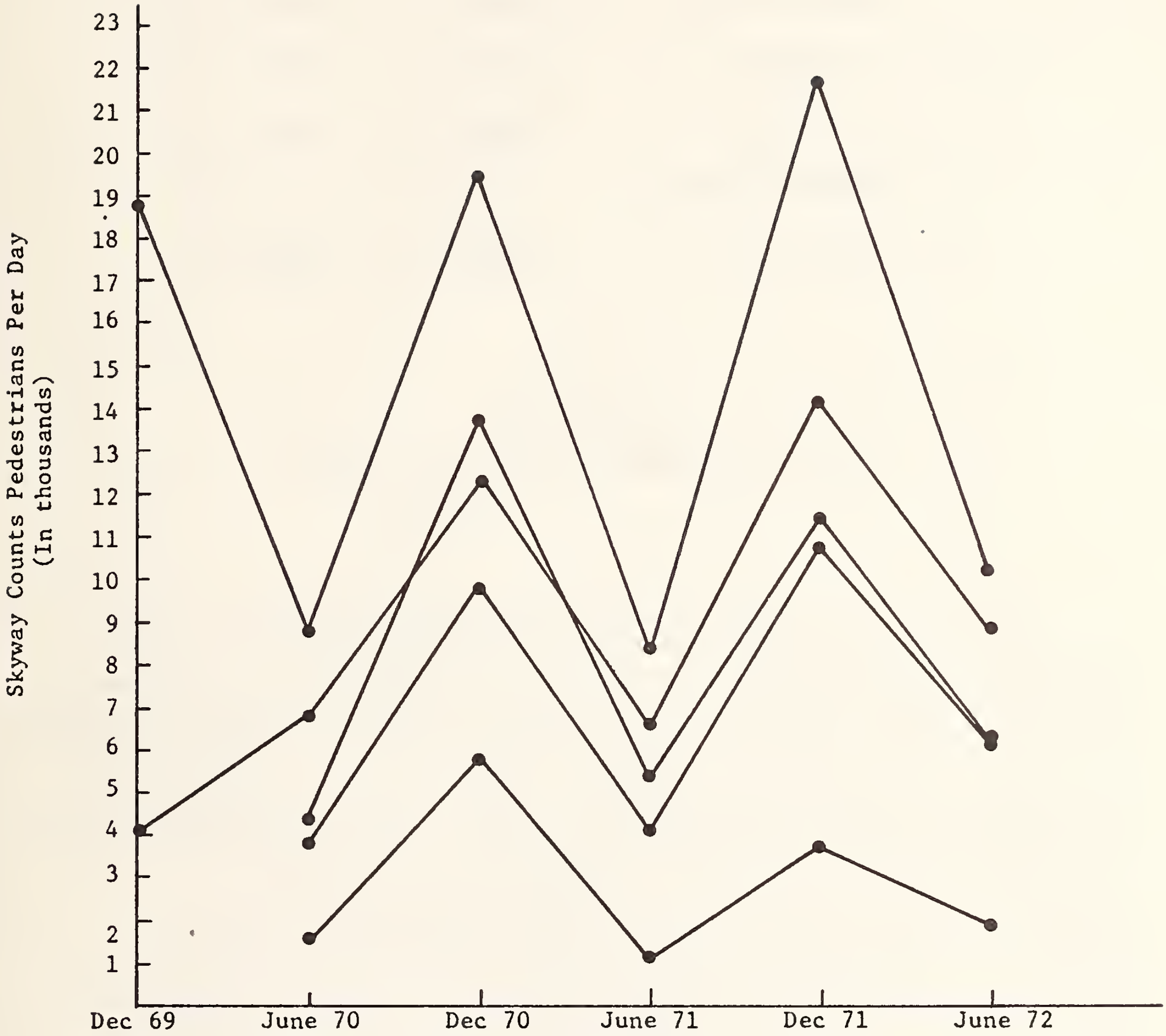


FIGURE A-5

SEASONAL SKYWAY PEDESTRIAN COUNTS

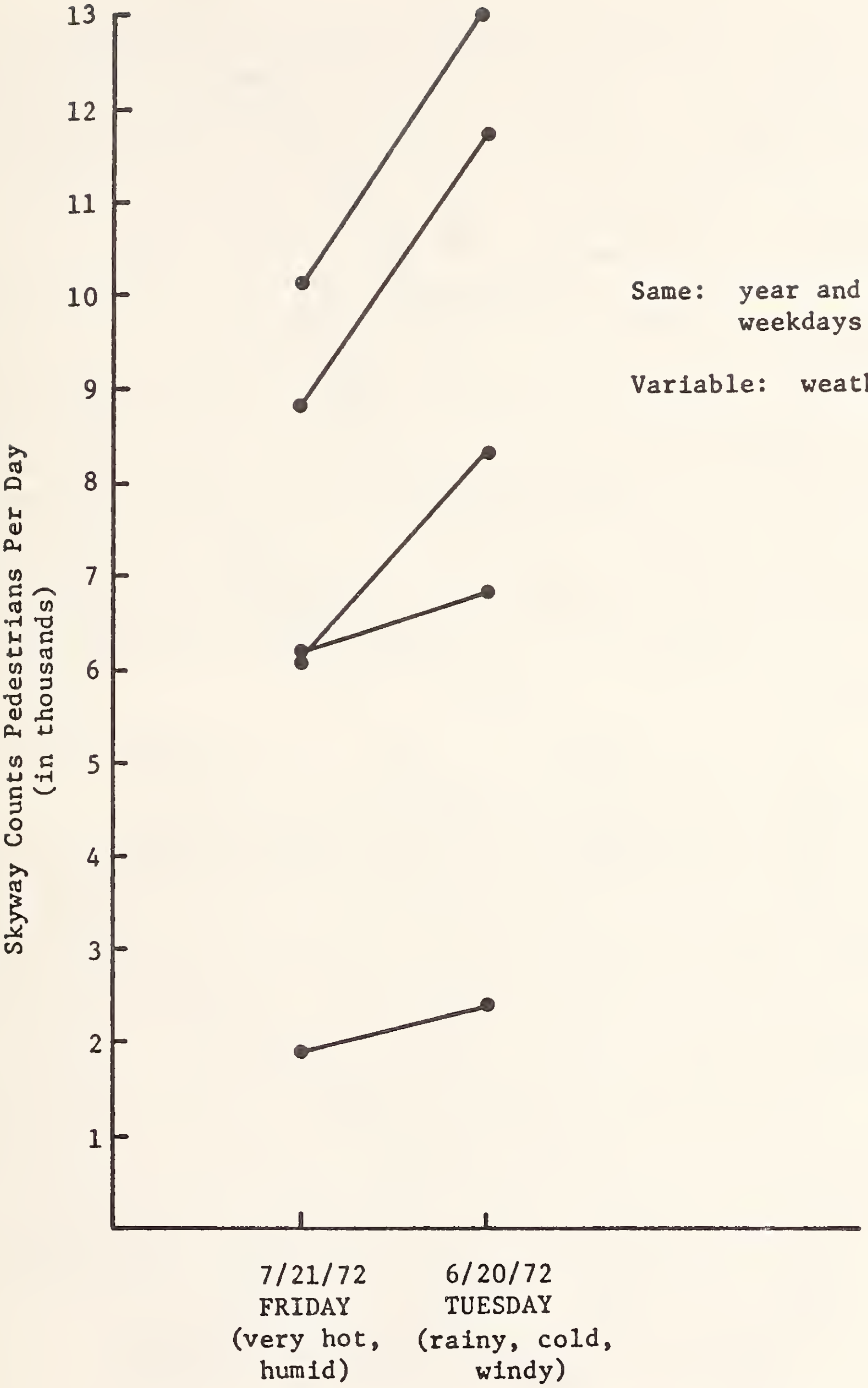
Site No.	Type	Pedestrian Counts Summer 1970	 December 1970
34	Skyway	8,964	18,900
33	Skyway	6,738	12,302
59	Skyway	1,520	5,829
	SKYWAY TOTALS	17,225	37,031
24	Exterior	5,204	6,835
23	Exterior	5,157	4,671
	EXTERIOR TOTALS	10,361	11,506
	TOTAL	27,586	48,537

TABLE A-4

COMPARATIVE SEASONAL IMPACTS OF SKYWAYS

Figure A-7 indicates the general trend in absolute skyway utilization over time. Note that the skyways implemented in 1969 showed a general decrease in utilization, possibly due to a partial transfer to other facilities, the decreasing uniqueness, or a growing perception on the part of the pedestrian that there was little benefit associated with these early singular improvements. However, as the system became more extensive in 1971, utilization increased substantially, even dramatically reversing the earlier decreases. Although 1973 counts have only recently become available, a preliminary examination indicates that the inclusion of the IDS Center and its four radiating skyways into the system has caused a major adjustment in the utilization pattern. Total utilization over the entire system has increased, but some skyways experienced decreased volumes while others remained generally constant.

The IDS skyways were apparently causing increased utilization overall, but were also creating shifts in the patterns of circulation; this effect will probably have stabilized by the summer of 1974. It should be noted that the general trend toward increased skyway



Same: year and season, different weekdays

Variable: weather

FIGURE A-6: INCLEMENT WEATHER COMPARISON

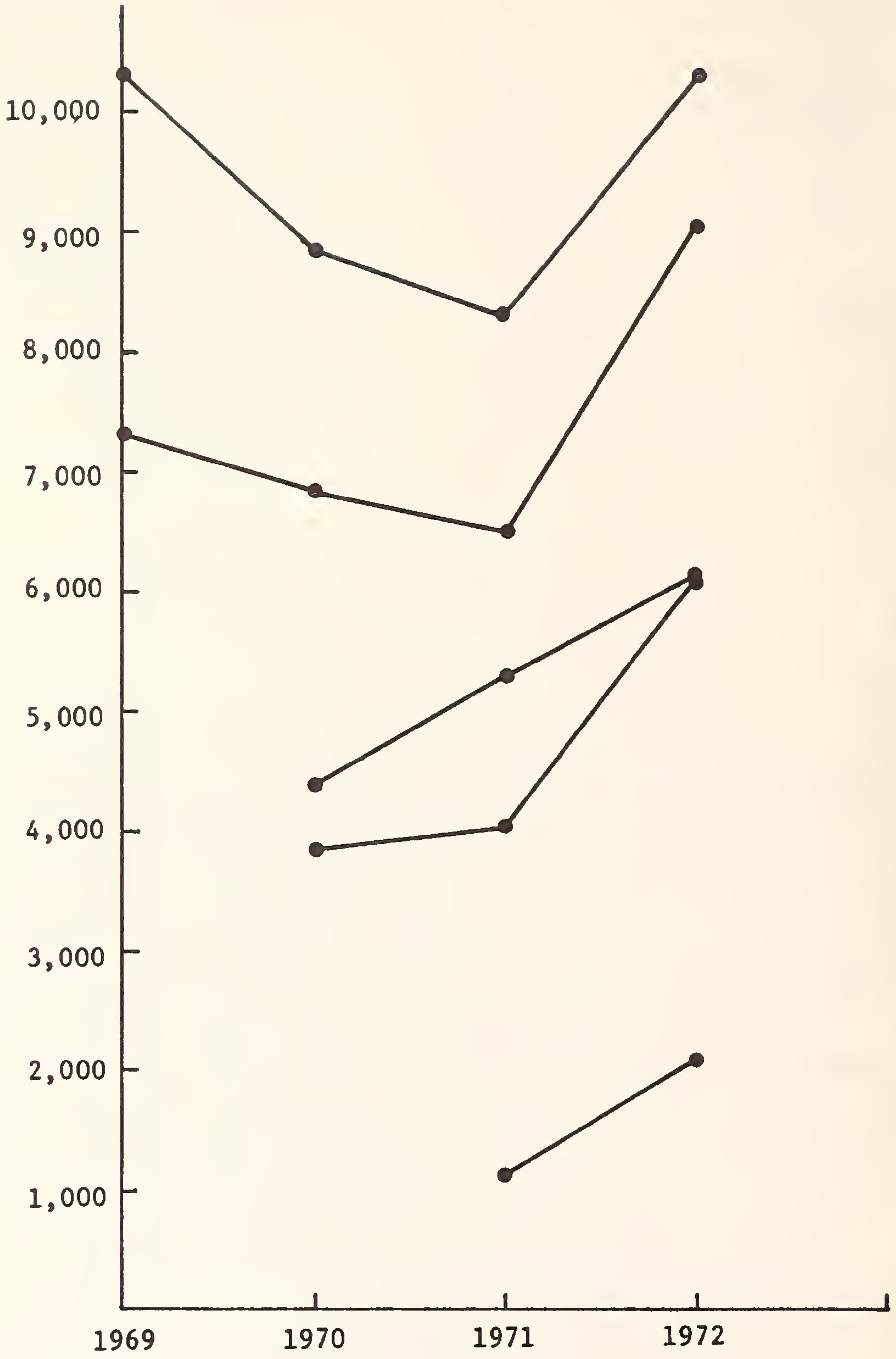


FIGURE A-7: PEDESTRIAN COUNT ON FIVE SKYWAYS volumes has taken place while the counts on the sidewalk have shown generally stable (and sometimes decreasing) utilization.

The relative use of skyways are directly affected by nearly all of the pathway attributes discussed in Chapter 5. Where skyways are associated with extensive new development such as those abutting the IDS Center, pathways are direct, coherent, require little or no vertical change, are anchored at both ends by substantial pedestrian attractors and generators, and are associated with intense retail activity. Observation, supported by recent counts, suggests a high level of utilization and "success." Where skyways link existing development, some sacrifices have been made; many pathways require substantial redundant vertical change between origin and destination. Some connections (between banks, for example) are devoid of any attracting activity. These pathways still "work," however, in the sense that they are utilized because they have one or more attributes that contribute to success. Alternative pathways usually involve vehicular conflict, exposure to the elements, or more indirect movement than that afforded by the skyway. Finally, they succeed because they are part of an overall system concept which succeeds. The Minneapolis skyway system yields benefits that seem to exceed those which would be derived from each of its elements considered separately.

A. 3. 4 Summary

Connections and Access: All skyways are private facilities in terms of ownership, maintenance and operation. No skyway is accessible directly from the street right-of-way. Each skyway is accessible only by first entering and penetrating into a building and then utilizing the vertical movement system within that building to move to the skyway. The most common means of vertical movement within most major buildings that are connected by skyways is an escalator. However, in several instances stairs, ramps and elevators are the only means of gaining access to a skyway without first moving horizontally and vertically through the interior of a private building. Because the system is composed of a series of private facilities (department stores, banks, parking ramps, offices and hotels) linked together by second level skyways, this has resulted in several atypical circumstances which affect our analysis:

- Closing any respective facility for business results in closing the second level link and greatly reduces the continuity of the system. When one facility is open but another connected by a skyway is closed, the skyway is rendered inaccessible (a dead end or discontinuity is created).

- Because the skyway system is directly connected to the interior circulation systems of private facilities, circulation through the skyway system depends on the interior semi-public circulation systems within each particular facility which the system connects. This results in several less desirable conditions:

  (i) Extensive use of various elements of vertical movement (i.e., stairs, ramps, escalators, elevators) to connect levels in an attempt to define a contiguous system. In some cases to move from the second level in one block to the second level in another block directly adjacent, a pedestrian will encounter a total vertical change of 70-80 feet. In some parts of the system a pedestrian will be moving up, then down, then up to reach the same elevation in the next block.

  (ii) Continuity is also broken by several reversals and sharp changes of direction. In moving from one block to another a pedestrian will encounter several discontinuous turning movements as well as travel back in the same direction as his origin to reach his destination, all of which has the net result of reduction in orientation.

  (iii) Since the system must utilize the interior second level circulation system within the envelope of each private facility, the pedestrian will encounter, in some instances, a lack of activity along his journey. For example, the second level of a private bank, office building or hotel was not designed to accommodate a skyway connection and therefore has not adjusted either the access to or location of its activities.

(iv) Since the system is private there is no coordinated system of signing and directional graphics, and no codes have been established by the city for this purpose. The result has been a complete lack of orientation in some links of the system. In some cases, however, this is actually intentional. In the case of routes passing through a department store, for example, no directional signing leads the pedestrian to the skyway so that he will spend more time exposed to the merchandising areas, and consequently be more likely to provide additional revenue to the store.

(v) Visibility is limited where the system must penetrate into the interior corridor system of existing private facilities. Visibility, however, is maximum in the skyways themselves where they extend through air rights above a street.

Elements of the System: The skyway system is composed of a series of elements related to the pedestrian pathway. Most of the pedestrian accommodations are related to enclosure from extreme climatic conditions and maximum visibility in the skyways themselves. There is, however, a distinct lack of other pedestrian amenities:

- No seating at the second level;
- No plantings, water fountains, trash receptacles;

- No provision for handicapped or nonambulatory pedestrians; and

- Several circulation impedances (e.g., revolving doors).

Other Factors Affecting Construction Costs: A major cost component of construction is the difficulty of connecting the skyway to an abutting property. This connection usually involves:

- Underpinning the superstructure of the abutting facility;

- Modifying a large section of the building facade physically and structurally to receive the walkway;

- Relocating some of the activities and functions on the level;

- Constructing additional skyway support structure directly adjacent to the linked facility; and

- Employing stairs and ramps to correct adjustments in floor elevations.

Evaluation of the System: The Minneapolis skyway system can be evaluated with respect to three major characteristics--those dependent upon the type of facilities linked, those dependent upon the activity or trip purpose, and those involved with private ownership and operation.

Characteristics Dependent Upon Type of Facilities Linked: An evaluation of Minneapolis skyways must be viewed with regard to the types of adjacent facilities they attempt to link. There are three specific types of conditions in this city:

- Skyway connecting new construction;
- Skyway connecting new and existing construction; and
- Skyway connecting existing construction.

The evaluation of each skyway within the total system is contingent upon one of the three identified conditions listed above. Factors measuring both the cost and the effectiveness of the system must be adjusted to fit each of the three conditions. For example, one would expect less change in elevation along a similar path connecting a new facility to an existing one.

Characteristics Dependent Upon Activity or Trip Purpose: In addition, activity linkage and trip purpose must also be considered in assessing the effectiveness of any given skyway linkage. In Minneapolis several activity linkages occur:

- Retail to retail;
- Retail to office/finance/business services;
- Office/business service to office/business services; and
- Skyway on second level movement to at-grade pedestrian movement (Nicollet Mall and other street level pedestrian activity).

Although evaluating factors are similar, each trip purpose implies a somewhat different set of relationships or priorities among the evaluating criteria, and these priorities must be addressed prior to evaluation. For example, the value of convenience or time savings may be greater for a shopping trip than for a journey-to-work trip.

Characteristics of Private Ownership and Operation: The Minneapolis skyway system has been developed and financed entirely with private funds. It is therefore the sole joint responsibility of private owners, joined by each skyway, to maintain and operate the skyway system. Skyways are considered as private development and are taxed by the city as would be any real estate improvement. Tax revenue generated by each skyway ranges from $5,000-7,000 annually. The skyways which extend over major street right-of-ways are only theoretically in the air rights above a public right-of-way, because, unlike most areas, invidual parcel property lines and titles extend to the centerline of each street in Minneapolis. Therefore each property owner must actually dedicate a portion of his property to public use or public domain so the city may obtain a dedicated public right-of-way for the purposes of constructing a street. This has resulted in certain legal incumbances as well as operational difficulties. Minneapolis law states that if a facility (such as a skyway) is maintained as a public service continuously for a periof of 17 years, it becomes Public Domain by Prescriptive Right on the Adverse Possession Clause. So that individual establishments may retain private ownership, the entire skyway system is closed to the public one day each year, otherwise it will revert to public use.

Private property ownership to the centerline of streets also causes other difficulties. Many buildings have been built with basement areas projecting under the street right-of-way. This requires extensive, costly reworking of the substructure during surface improvements such as Nicollet Mall. The basement areas also restrict the space available for major utility lines.

The private ownership of the Minneapolis skyways has imposed certain very specific restrictions for pedestrian users, notably that no skyway is accessible directly from the street right-of-way. Each skyway is accessible only by first entering a building and using the vertical movement system within that building for access to the skyway system. The most common means of vertical movement within most major buildings connected by skyways is an escalator. However, in several instances stairs, ramps and elevators are the only means of gaining access to the skyway system.

Because the system is composed of a series of private facilities several atypical circumstances result:

1. When any respective facility is closed for business this results in closing the second level link and greatly reduces the continuity of the system. In situations where one facility is open and another is closed and they are connected by a skyway, the skyway is rendered inaccessible (a dead end or discontinuity is created).

2. Because the skyway system is directly connected to the interior circulation systems of private facilities, circulation through the skyway system must interact with and depend upon the interior semi-public circulation systems within each particular facility.

The primary effect of a private system is that the city has no actual control over the implementation or operation of the system. Such controls would normally establish design and planning criteria for access, dimensions, signing, lighting, use, accommodation for the handicapped and other items related to public rights-of-way. In effect the second level system, in terms of utility, paraphrases the at-grade pedestrian domain, i.e., the sidewalk, where such controls are imposed.

A.4 CINCINNATI

A.4.1 Background - The CBD Renewal Plan

Factors Contributing to the Plan's Creation

By the early 1960s, economic stagnation of the central business district of Cincinnati had reached serious proportions. Although firms were leaving the central business district, there was still not enough space for cars and parking. While the riverfront was a tangle of warehouses and railroad tracks; the wholesale produce shipping function on the Ohio River was declining. Partially because of the deterioration of the downtown area, there had been a decline in weekend and nighttime activity and in mass-transit use.

In the three years previous to 1962, Cincinnati had tried three times to arrive at a downtown plan -- but each effort had failed. The Cincinnati City Council had abandoned one plan proposed by the City Planning Commission because they could not agree on an underground garage. Another scheme had been rejected because it proposed closing a number of streets to automobile traffic. A third study, sponsored by the real-estate and development interests, had also failed.

In 1962, at the request of the City Council, the City Planning Commission proposed a new Working Review Committee that would review and pass on planning proposals, thereby establishing a framework for a new Downtown Plan to be developed. This committee consisted of 18 representatives from the City Administration, the City Planning Commission, the Downtown Development Committee and civic interests at large. The City Manager also decided that it was necessary to have outside planning consultants, and by September had arranged for three consulting firms to become involved -- urban planning consultants RTKL Associates, transportation consultants Alan M. Voorhees and Associates, and economic consultants Hammer and Company.

The Planning Process

To assure a process that would act logically on a hierarchy of decisions, an ever-increasing level of detail of planning decisions was proposed. Using this process, when the highest level had been attained, all decisions were made; that is, decisions were made before the plan was completed. This process allieviated the often fatal process of completing the planning before making any decisions.

After each committee meeting, the City Council convened and, in most cases, approved the decisions that had just been made. The final plan exists in the form of approximately 250 ordinances that vary from expressions of philosophical intent to specific statements governing the width of sidewalks.

Basic Elements of the CBD Plan

The effect of the completed plan was to give each of the blocks in the renewal area a strongly delineated functional relationship with the rest of the core. The statements governing sidewalk widths and access points and the suggestions regarding arcade sections and second-level pedestrian circulation systems helped to serve this purpose.

The plan that the Working Review Committee produced for downtown Cincinnati divided the central business district into two segments -- the core area and the frame around it. The decision by the City Council to proceed with major public commitments in both areas, and the prospect of reasonably priced CBD sites, induced complimentary commitments from the private sector.

A.4.2 The Pedestrian System as Part of the CBD Plan

Emergence from the Planning Process

A major concern of the Working Review Committee was that congested traffic, pedestrian-vehicular conflicts and inadequate parking facilities would curtail sales of downtown retail stores. After categorizing streets by specific use, the planners decided to encourage drivers to park their cars at the perimeter of the CBD. Since 54 percent of the people who come into the CBD do so to shop, the plan concentrated parking facilities in and around the retail boot. Within the core itself, the plan allocated an additional 4,830 spaces; in the frame around the core, the plan projected another 10,000 spaces.

Recognizing the need for pedestrians to be able to walk comfortably within the core, the planners opted for a second-level walkway to circumvent the retail boot and extend from the convention hall through the office area and down to Riverfront Stadium. At grade level, the plan identified a program for improving pedestrian movement by enhancing sidewalks by the use of arcades and by creating a pedestrian mall around the historic Tyler Davidson Fountain area.

Since the second-level pedestrian walkway system will be developed and implemented continuously over a long period of time, planning and design standards had to be established to ensure maximum coordination of public walkways with private urban development projects in the downtown core area. This has been accomplished as a part of the CBD renewal plan's series of legal ordinances. The design criteria for the systems have been defined; the definitions have been developed as a function of legal controls concerning the following:

- continuity (systems configuration);
- location (access);
- dimension;
- safety (lighting levels, site lines, security provisions);
- engineering;
- amenities (street furniture, landscaping); and
- equipment (mechanical systems, lighting, graphic systems, street furniture).

Transportation Context of Downtown

The pedestrian movement system was developed in the context of a modified vehicular traffic network. The transportation system consists of arrangements for the automobile, mass transit and pedestrian circulation. The characteristics of these separate transportation elements in downtown are dependent upon the function they serve within the overall downtown traffic network.

Currently, the downtown system is automobile dominant, based upon an expressway network. While the expressways do not incorporate transit facilities, they are usable for express bus service and will benefit the transit system. The expressways form a partial loop around the downtown and, in fact, define its boundaries. They provide a rapid means of regional transportation to the very edges of the downtown and are linked, beyond the metropolitan region, to the interstate system. While the expressways remove much of the through traffic, there continues to be some through traffic to be accommodated in the downtown in addition to core-destined traffic.

Specific Objectives of the Pedestrian Circulation System

The pedestrian facilities plan seeks:

- to encourage multipurpose use of the downtown by permitting the visitor to park at one point and to circulate freely and comfortably on foot to other points in the downtown.
- to create the maximum opportunities for general interchange between major functional land use activity areas of the downtown.
- to create a pedestrian-dominated environment fulfilling his practical needs for safety, shelter and rest and his desire for aesthetic surroundings. Within this broad objective for pedestrian environmental amenities are the specific goals of creating a 24-hour environment with total public access and developing an organized system of pedestrian-scaled spaces with the focal point at Fountain Square in the heart of the CBD.
- to establish a second-level concourse designed and positioned to function as a primary pedestrian route supplemented by the pedestrian activities at the grade-level pedestrian concourse.

A.4.3 System Description

The pedestrian movement system is composed of several elements all of which are linked together to form a movement network (Figure A-8).

Pedestrian Streets

The pedestrian street sidewalks are widened on (1) the north side of Fifth Street at Fountain Square by closing the north traffic lane, (2) Race Street between Fifth and Seventh, (3) the south side of Fifth Street between Vine and Sycamore, and (4) Garfield Place, including the closing of Eighth Street between Race and Plum.

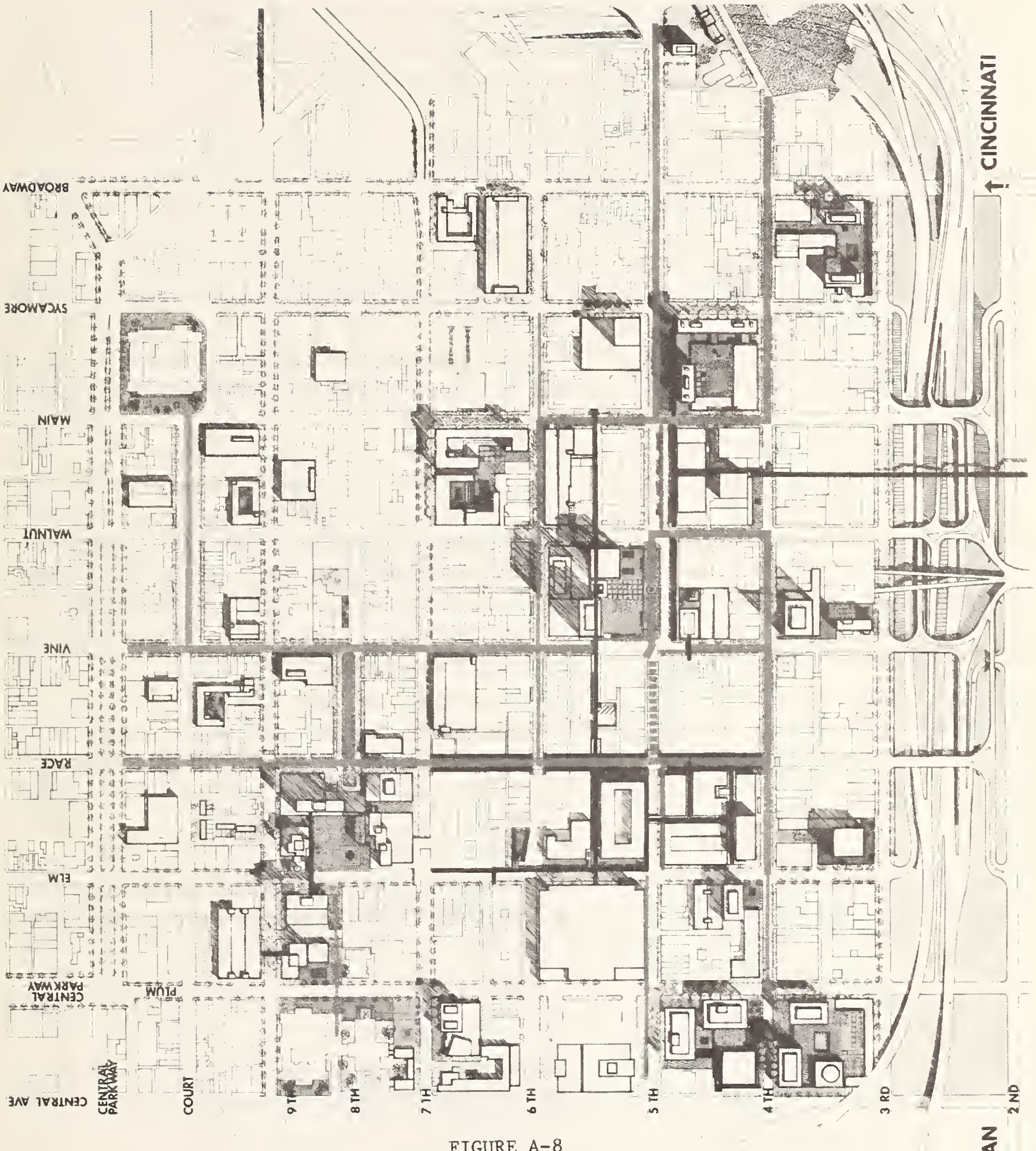


FIGURE A-8

CINCINATTI PEDESTRIAN SYSTEM

Fountain Square is the central focal point for pedestrian assembly in the downtown. With the closing of the north traffic lane of Fifth Street, a civic plaza in Block A, and the widening of the sidewalk on its south side, a new pedestrian space has been created at the heart of the downtown. Moreover, the southside arcade permits the movement of pedestrians under cover from the Government Square bus shelter westward beneath a galeria to Race Street. This galeria over Fifth Street from Vine to Race, if proven feasible, could be a unique symbol for Cincinnati.

A principal element in the pedestrian circulation system is Race Street. Here a totally new pedestrian streetscape is being created with patterned street and sidewalk surfaces, properly scaled streets, sheltered arcades, and street tree plantings. This street clearly states that it is a pedestrian street, even though it is traversed by minibuses and local buses.

Pedestrian Linkages

Pedestrian linkages relate points of origin to points of destination. The primary destinations are the retail shops on Race, Fourth and Fifth Streets. The prime originators of pedestrian traffic are:

- the shoppers' parking facilities in and around the core;
- the centers of office employment on Fourth Street, the Federal Office Building, the institutional offices to the east and the proposed new office complex in Block A;
- the housing concentrations on the central riverfront, in redevelopment Block E and on Garfield Place;
- the Government Square bus depot; and
- the Civic Center Convention facility.

These points of pedestrian origin and destination are linked together by a single system designed in two levels -- a second-level concourse (walkway) for express traffic and a grade-level concourse for local traffic.

Three important features distinguish the Cincinnati system. First, the office employment area on the east and the Civic Center on the west will, upon completion and integration with the walkway system, provide firm anchors and trip generators for pedestrian amenities. Second, the entire system is at one specified level requiring virtually no vertical displacement mechanisms (e.g., stairs, ramps) to change elevation between different parts of the system. Third, the system is fully operational on a 24-hour basis and fully accessible to the public along any of its segments because it is publicly owned and operated. The system is not subject to interruption or to segments becoming inaccessible when buildings and businesses close their doors.

The elevated express system permits a quick and comfortable journey from points of origin to prime points of destination at some distance aways, such as Race Street and the Convention Hall. The east-west leg of the concourse extends eight blocks from Main to Race Street. It is positioned at mid-block along the line of Opera Place so as not to compete with the Fourth and Fifth Street retail frontages. The north-south leg, which is on Elm Street, is designed to connect Garfield Place to the Convention Hall and Fourth Street retailing. The Elm Street location precludes its competing with the Race Street retail frontage. This second level concourse can advantageously be tied into certain buildings. However, its physical connection to buildings is not required for the proper functioning of the concourse. The two legs of the concourse can ultimately be connected through the Carew Arcade to Fountain Square, thus completing the circuit. The proposed pedestrian link from the Central Riverfront is an integral part of this express system.

The second level concourse is detailed as an enclosed pedestrian way. Its east-west leg provides for vertical access by escalators and stairs at the Federal Office Building, within the municipal garage in Block H, in the office complex in Block A and at the Vine and Race Street ends of Opera Place. Its north-south leg connects to the Shillito's department store and the Sixth Street municipal garage. It descends to grade at Elm and Seventh Streets, at the Sixth Street bus terminal, at the Convention Hall and in redevelopment Blocks D and G. The walkway from the Central Riverfront comes to grade in a terminal facility on the southside of Fourth Street. Its concourse continues over Fourth Street via a broad arcade in Block B to the Government Square bus depot.

The second-level north-south connection originates at Shillito's garage, crosses Elm Street and Seventh Street and, in its final phases, connects the four corners facing onto the intersection of Elm and Sixth Streets by four pedestrian bridges thereby forming a major pedestrian node.

Points of Connection Between Second-Level Pedestrian Concourses and Grade Levels

In accordance with the principle of providing a convenient number of points connecting the second-level concourse to grade level, vertical connection points have been located in areas of greatest pedestrian volumes. All vertical connection points are located in a manner that provides continuous 24-hour access between the street level system and the second-level system.

Physical Design Characteristics

The basic dimensions of the interior of the walkway are eight feet in height and 12 to 15 feet in width. The walkway carriage is primarily constructed of a cast-in-place concrete pathway with a ribbed bonnet which can be enclosed in a later phase.

A.4.4 System Utilization and Impacts

At present it is extremely difficult to evaluate fully the utilization of Cincinnati's second level pedestrian walkway system because at both terminals of the main trunk of the system, where the major trip generators are located, major construction is presently underway, effectively separating the system from its prime areas of utilization. Upon completion of the construction, the second-level walkway will link the major pedestrian generations. Until then, the construction zones will deprive the walkways of a full measure of even interim utilization. In addition, the absence of pedestrian volume counts at this time makes an analysis of utilization imprecise.

However, it is possible to make general observations about utilization patterns. Aside from the construction impedences, factors tending to diminish use can be found in the physical design of the system. As constructed, the system includes many unresolved spaces, alcoves and mini-plazas. This has resulted in a number of hidden and unlighted spaces both on and underneath the walkway structure. Sight lines are frequently obstructed by these configurations, causing significant security problems which may hamper total pedestrian acceptance.

Factors which would tend to increase utilization include public accessibility at all intersected streets, a single fixed level throughout with vertical displacement within the system's envelope, and 24-hour operation. Public maintenance and ownership, which, unlike Minneapolis, assures full accessibility to the entire system regardless of closings by businesses and buildings, will certainly contribute to the system's utilization.

It should also be noted that utilization patterns will continue to change and grow as redevelopment occurs within the CBD. Unlike most other cities which follow existing development trends with their pedestrian systems, the Cincinnati system has tended to lead the development market with firm proposals and actual construction preceding specific redevelopment plans. As a result, the ultimate pattern and level of utilization is not likely to emerge until some time after the Downtown Renewal Plan is substantially completed.

A.4.5 Facilities Costs

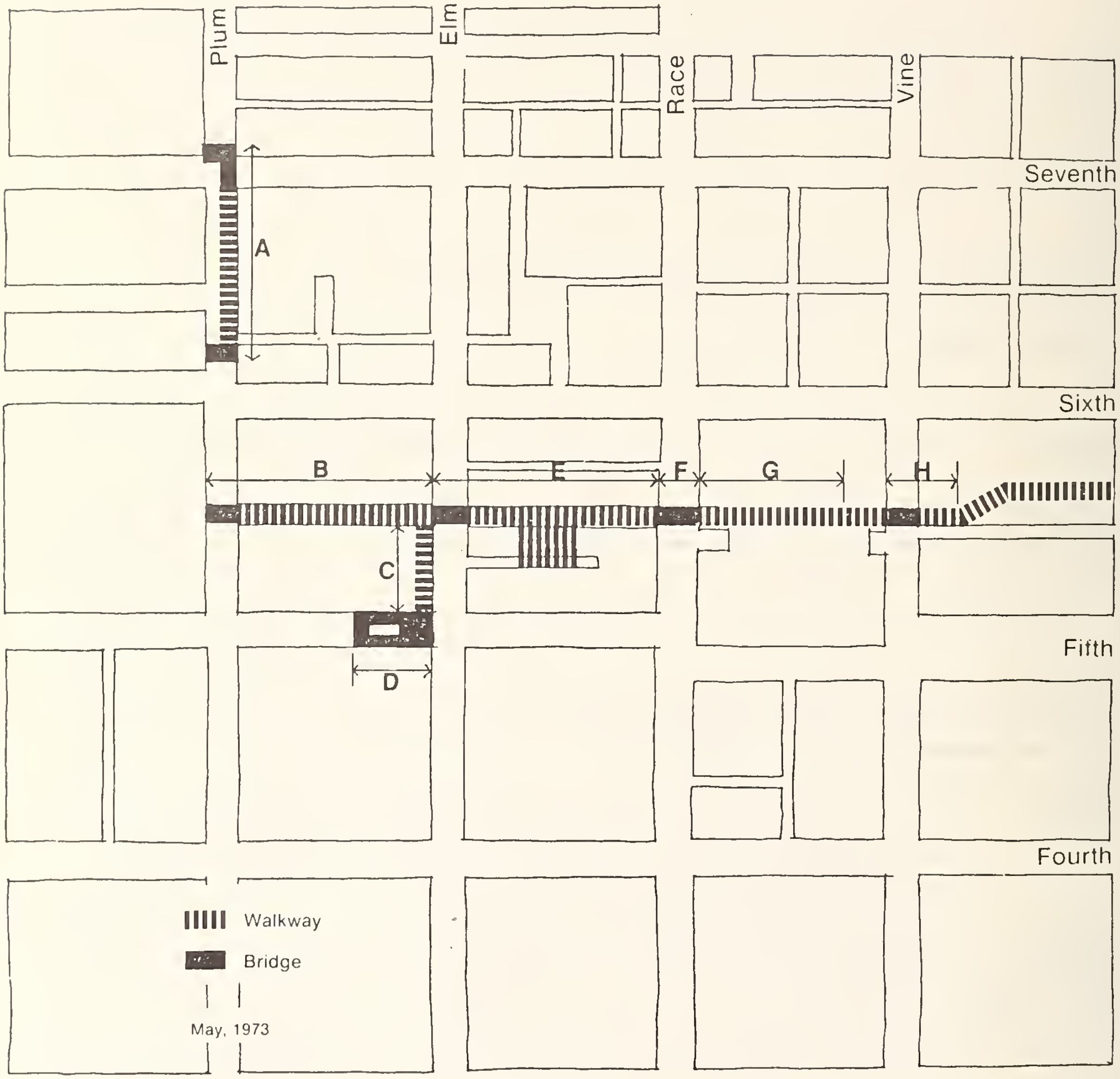
Following are construction cost data for second-level walkways constructed in Cincinnati. The walkways are all of concrete structure, they occur in the public rights-of-way and are roofed over but not enclosed. Financing was by Federal Urban Renewal monies. Cost data were obtained from Cincinnati's Urban Development Department. Sections are identified on Figure A.9.

Section A

Total Contractors Cost: $745,858* (bid)
Total Improvement Cost: $821,577
Date: 1968-70
Included: Three bridges; one pair of escalators; one permanent and one temporary stair; exposed metal deck ceiling; some skylights; concrete and terrazzo floor; two concrete and wood benches; concrete structure.
Remarks: Foundation problems -- vaults, etc., below sidewalks.
Approximate Cost per sq. ft. $ 50.00
Approximate Cost per lin. ft. $1,003.00

FIGURE A-9

CINCINNATI WALKWAY SYSTEM



Section B

Total Contractors Cost: $1,082,682 (bid)
Total Improvement Cost: Not yet available
Date: 1969-70
Included: One double bridge; two pairs of escalators; two double stairs; multi-level roofs; some skylights; 30' x 30' bays; light wells to ground level in alley; four small planting boxes.
Approximate Cost per sq. ft. $ 42.00
Approximate Cost per lin. ft. $1,066.00

Section C

Total Contractors Cost: $340,000 (negotiated)
Total Improvement Cost: $340,000
Date: 1968-69
Included: Cantilevered walkway; first "all concrete" deck (others are combinations of materials); open roof structure and skylights.
Remarks: Built to stand even if main portion of building is removed.
Approximate Cost per sq. ft. $ 112.00
Approximate Cost per lin. ft. $1,789.00

Section D

Total Contractors Cost: $386,955 (bid)
Total Improvement Cost: $386,955
Date: 1971-72
Included: "Platform" or "double bridge" design; similar to Section C but without roof; combination terrazzo/concrete/paving block floor; one pair of escalators; open well over Fifth Street; six planter tubs.
Remarks: Platform spans total right-of-way.
Approximate Cost per sq. ft. $38.00
Approximate Cost per lin. ft. Does not apply.

Section E

Total Contractors Cost: $1,299,402 (bid)
Total Improvement Cost: $1,637,074 (including $197,500 property acquisition)
Date: 1970-71
Included: Four building connections; two building connection stairs; two double stairs; one pair of escalators; periodic skylights and trees; three marble benches; two planters; one decorative sculptural fountain; one drinking fountain; telephone booths.
Approximate Cost per sq. ft. $ 44.00
Approximate Cost per lin. ft. $2,393.00

Section F

Total Contractors Cost: $250,000 (negotiated)
Total Improvement Cost: $250,000
Date: 1969
Included: Bridge only; same general design and construction as Section C.
Remarks: 66' clear span over right-of-way.
Approximate Cost per sq. ft. $ 208.00
Approximate Cost per lin. ft. $3,125.00

Section G

Total Contractors Cost: $350,000 (negotiated)
Total Improvement Cost: $350,000
Date: 1969
Included: Freestanding walkway; one pair of escalators; 15' x 30' span; concrete and terrazzo floor; metal (bronze) and glass hand rail system.
Remarks: Built on existing garage foundations.
Approximate Cost per sq. ft. $ 41.00
Approximate Cost per lin. ft. $842.00

Section H

Total Contractors Cost: $434,188 (bid)
Total Improvement Cost: Not yet available.
Date: 1972
Included: Freestanding walkway; one each metal and terrazzo stair (3 switchbacks); one bridge, spans right-of-way (bridge roof higher than walkway roof); 15' x 15' bays; concrete/ terrazzo floor.
Remarks: No cost available on portion within bank building.
Approximate Cost per sq. ft. $ 73.00
Approximate Cost per lin. ft. $1,451.00

Note: Contractors costs for all sections are for construction only. Costs do not include design, engineering, inspection, testing, etc.

Although the average bid cost of the second-level walkways has been $105.90 per square foot, for other segments of the walkway, costs have been as much as $300.00 per square foot. This was principally due both to extensive utilities relocation as well as to the inclusion of a new utilities network which is required to accommodate full enclosure in a later phase of development. Fully enclosing the pedestrian system requires an independent mechanical system both within the walkway structure and within the sideway areas beneath the path of the walkway. The location of mechanical vaults has added considerable cost to the system.

A.4.6 Local Contingencies and General Conclusions

There are several pertinent features that differentiate the Cincinnati walkway system from other similar CBD systems. Unlike any other city studied, the Cincinnati system has been implemented as part of an overall renewal plan in the form of a series of legal ordinances (similar to special district zoning laws). In this manner, its physical characteristics are defined legally and compatibility is ensured regardless of the nature of future redevelopment.

The system basically consists of a horizontally displaced pathway running with its major access east-west for a twelve-block area in the center of the Cincinnati Central Business District. The system was not constructed in the right-of-way of a major street within the CBD traffic network, but rather occupies a right-of-way that penetrates through the center of major downtown development along an existing right-of-way that was formerly a service alley.

The vertical elevation of the pathway is held constant throughout its entire length. As is pointed out in the preceding section on design criteria, elements of walkway design such as a fixed vertical elevation and accessibility adhere to rigid criteria imposed by the municipality. All development occurring either adjacent to or within the pathway has been fully coordinated so that the second floor elevation of this development coincides exactly with the fixed elevation of the walkway. Consequently, there is virtually no change in vertical elevation along its path.

Areas in the corridor below the walkway continue to supply service access to abutting property occupants. Limited pedestrian circulation is maintained at the first level, although pedestrian circulation is directed principally along the second level. Pedestrian circulation occurring at the first or grade level is not encouraged as there are various points of vehicular-pedestrian conflict that occur along its path.

The system, which is currently in the final phases of construction, serves to link three major pedestrian generators. The Civic Center and the Southern Ohio Bank complex exist at either terminal of the system, and Fountain Square (a major civic square with underground parking) is connected at the mid-point of the system.

In addition to flanking existing and newly developed abutting property, the pathway penetrates through many existing buildings in several areas. Again, as a function of municipal control, the areas where the public walkway penetrates through lobbies and reception areas of privately owned space, extensive coordination is apparent in terms of the use of materials, public accessibility and standards of lighting and signing. All elements of the pathway, including those building spaces it penetrates, are directly accessible to the public on a 24-hour basis. In addition, at each interval where the second level system intersects a major street network, there is continuous accessibility from the street right-of-way to the second level. This is accomplished through the extensive use of vertical circulation elements such as stairs and escalators.

Unlike the Minneapolis skyway system, the Cincinnati walkway system has achieved a full measure of public accessibility of both its pathway and the linkages of that pathway to the major street network within the downtown area. However, achieving this level of accessibility has not been without impact. The following list is composed of various aspects of the system that appear to be the result of a system that supplies continuous accessibility on a 24-hour basis.

- As a result of the configuration of the system and its location with regard to peripheral development and as a result of certain design features, there are various segments of the system that are difficult to maintain. Access to the second level is difficult for maintenance crews.

- Because the second level system is directly linked to each intersecting street right-of-way, extensive use of costly vertical circulation elements has been necessitated.

- Both the configuration and the design of the system included various segments along its path in which the pedestrian is not visible to public areas where security would be maintained. A security problem particularly in the non-daylight hours has resulted.

- The net effect of the location of the pathway, its micro-design elements and the extensive use of unencased vertical circulation elements (i.e., stairs or escalators where the elements have not been enclosed in a structure, thereby exposing the spaces between the stair or escalator and the levels it connects) has resulted in producing a peculiar pedestrian environment. This environment is made up of a series of small alcove type spaces, all of which lack visibility, and therefore represent a major problem in terms of safety. Those parts of the system that exist at street level or underneath the path of the second level are not designed to be used by pedestrians in the non-daylight hours. This is evidenced by the lack of proper lighting and other necessary amenities to ensure pedestrian safety. However, because of the high degree of accessibility to all areas at the first and second levels, pedestrians are free to move unimpeded throughout areas which must be defined as high risk.

A.5 LANCASTER, PENNSYLVANIA

A.5.1 Description of System

Lancaster Square represents a major redevelopment effort in the center of downtown Lancaster. This multi-use redevelopment project was the joint undertaking of both public and private monies during the period of 1966 through 1971. The Lancaster Redevelopment Authority and The Second North Queen Co. Inc. (a private developer) jointly participated in the development of Lancaster Square. In addition, some HUD Urban Renewal monies were available for the project.

Lancaster Square is developed within a four-block area in the center of downtown Lancaster (Figure A-10 and A-11). This area is bounded by W. Chestnut Street, N. Christian Street, E. Orange Street, and N. Market Street and represents approximately a ten-acre site. As originally conceived, the development was to include the following:

1. Hess Department Store (five levels) approximately 300,000 square feet
2. A second major department store of approximately 100,000 square feet
3. Two major office towers
4. A Hilton hotel
5. Two continuous levels of related retail, commercial space 150,000 to 250,000 square feet
6. Two major 1200 car (self-park) parking garages
7. A major public plaza
8. A major three-level public walkway system

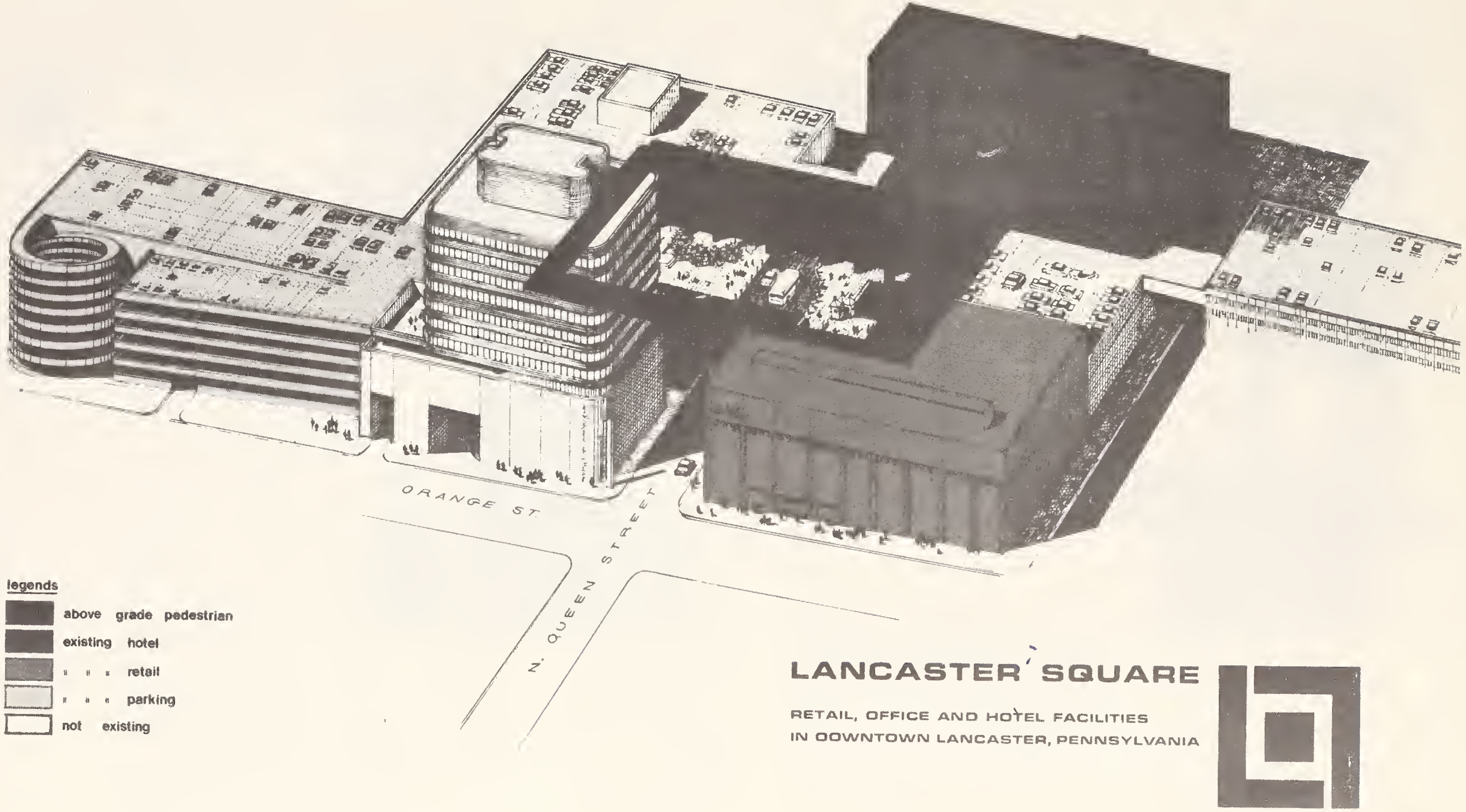

ORANGE ST.
N. QUEEN STREET
legends
above grade pedestrian
existing hotel
" " retail
" " parking
not existing
LANCASTER SQUARE
RETAIL, OFFICE AND HOTEL FACILITIES
IN DOWNTOWN LANCASTER, PENNSYLVANIA

FIGURE A-10

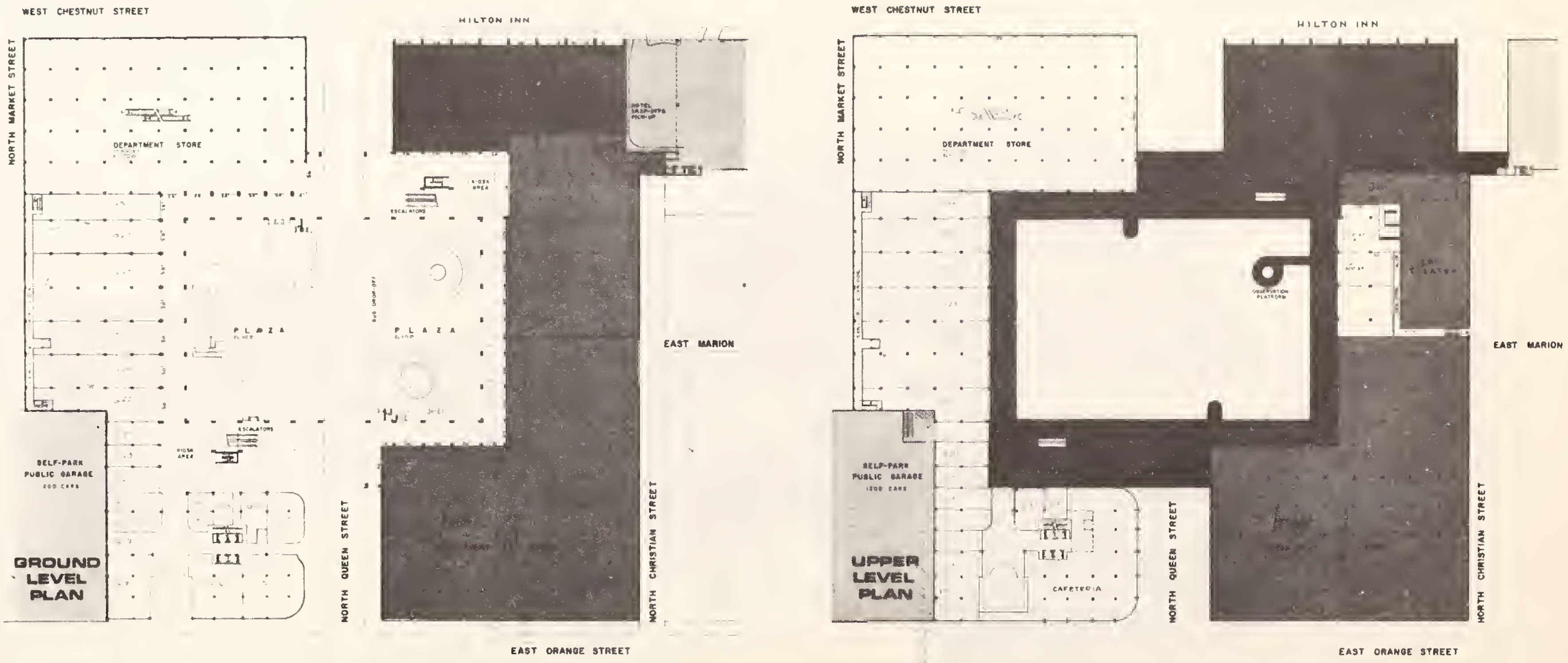


FIGURE A-11

LANCASTER SQUARE - PLAN

A.5.2 Concept

The major unifying element of this development is a three-level public walkway system which connects the four major blocks of development at the second and third levels above the street right-of-way. The configuration of the walkway forms a square which extends in two places above and over N. Queen Street (a major downtown traffic artery) connecting both major parking facilities and the major new development on both sides of the main thoroughfare. The walkway bisects the centers of all four peripheral blocks.

At street level, a major civic plaza is contained within the space enclosed or defined by the walkway system. All areas on the periphery of the walkway were to accommodate the major land use activities listed above. In some ways the magnitude of this multi-use development can be compared to a major regional shopping facility in terms of the approximately one million square feet of connected retail space served by well over two thousand parking spaces. The walkway at the second level joins the two major parking facilities to the major retail and commercial space thereby forming the continuous space for unimpeded pedestrian movement.

Access to the second level is by stair or escalator from the street plaza level and by elevator and stair from various points within the abutting properties surrounding the system. At the third level, the walkway takes on the characteristics of a typical urban street. The system connects upper level store parking areas as well as the diametrically opposed major parking garages.

The third level vehicular street (which occupies the space directly above the second level pedestrian walkway) is directly accessible to the downtown street network and provides two major points of accessibility directly from the street system to parking areas within Lancaster Square. Along the inside of this "street" is the continuation of pedestrian pathway which functions as a sidewalk would at street level. In this case, pedestrian access to land use activities on the periphery of the development is possible only by crossing this moderately travelled vehicular right-of-way. In the sense of pedestrian-vehicular conflict, the third level of Lancaster Square operates no more efficiently than would any pathway along a typical street in a downtown area (i.e., a vehicular right-of-way flanked by pedestrian sidewalks).

The walkway system is for the most part covered but not enclosed. The outer edge of the walkway is enclosed by abutting property. However, the inside edge of the walkway (i.e., that which faces into the plaza) is not enclosed. Ceiling-mounted heating units provide climate control during the severe months of winter. No climate control is provided during the summer months. The structure of the system is quite massive in appearance and seemingly out of character with downtown Lancaster.

A.5.3 Current Status

Of the anticipated development listed above, after several years only the following has come to fruition: the hotel, the two major 1200 car parking facilities, a Hess department store, the public plaza and the three level public walkway system. The remainder of the abutting property is cleared and vacant. In addition, all of the constructed space along the path of the walkway that was to accommodate major office and retail land uses remains unfinished. A recent article in Business Week, September 1, 1973, speaks of the successes of Lancaster Square. The article points out that the $8 million Hess department store has gone out of business and closed, with a loss placed at more than $2.5 million. None of the other retail/office space has been occupied. The Hilton Hotel, the only other principal occupant, is also experiencing a much below average occupancy rate. Of the total space in the retail arcade at the lower level within the building envelope of the Hilton Inn less than one percent is occupied.

There exists other evidence of the doubtful outcome of the project. Specifically, there are several elements of the system, especially on the third level, that remain to this date unfinished. It is apparent that construction activity was terminated prior to the completion of the project.

A.5.4 Factors Contributing to the Failure of the Project

There are several direct and indirect factors which contribute to the ill success of Lancaster Square. Those relating to the financial market include:

1. Tight construction dollars in the late 1960's and 1970's.

2. Regional market competition. Within four minutes driving time from Lancaster Square, on the fringes of downtown Lancaster, exists one of the largest regional shopping centers in the United States. Park City was planned and developed during the same time as the Lancaster Square redevelopment effort. There is no question that this regional shopping facility has effectively contributed to the failure of Lancaster Square in terms of its market potential. Other factors causing failure have been identified through discussions with the Second North Queen Co. Inc. These factors related principally to poor management, poor overall direction and piecemeal development of the project.

From the standpoint of the overall planning of the pedestrian system, there is one factor that should be highlighted in contributing to the failure of the development. The Lancaster system specifically fails in the area of project phasing. There was no regard to a phasing program that would have responded to the need for linking related land use activities as they were developed over time. Consequently, Lancaster Square consists of a three-level walkway system which connects nothing more than vacant property. One of the reasons given for the lack of phasing of the system lies in its physical design characteristics. Since the third level of the system was to accommodate vehicular traffic, the entire structure, both first and second levels, had to be initially designed to accommodate for automobile traffic. This in turn placed an unusual constraint on phasing of construction. To build only part of the system, that is specifically the second level, and add the third level at some later date was not practical financially since the structure had to be initially designed to carry the additional load of automobile traffic at the third level. There are certain cost penalties related to phasing the construction and construction cost was lower by building the structure at one time. Therefore, due to economic considerations related to initial construction cost, phasing was not considered a priority.

FHWA
R&D