Implementation
Package 74-5

a manual for planning pedestrian facilities

DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Washington, D.C. 20590
June 1974

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
Implementation Package 74-5		

4. Title and Subtitle	5. Report Date
A MANUAL FOR PLANNING PEDESTRIAN FACILITIES	
	6. Performing Organization Code: 289-51835-40
7. Author(s) Summary prepared by J.C. Prokopy from A Comparison of Costs and Benefits of Facilities for Pedestrians by W.G. Scott and L.S. Kagan	8. Performing Organization Report No.
9. Performing Organization Name and Address Peat, Marwick, Mitchell & Co., and RTKL Associates Inc. 1025 Connecticut Avenue, N.W. Washington, D.C. 20590	10. Work Unit No. (TRAIS): 1 - 2 11. Contract or Grant No.: DOT-FH-11-7966
12. Sponsoring Agency Name and Address Office of Research and Office of Development Federal Highway Administration Department of Transportation Washington, D.C. 20590	13. Type of Report and Period Covered: Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

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16. Abstract

This manual provides the planner and the engineer with the basic considerations necessary to plan pedestrian facilities or systems of facilities. Included are the basic concepts in pedestrian trip generation and movement, and basic types of facilities available to the planner, categorized by horizontal, vertical, and time separations.

Each of the types of impacts to users and nonusers of pedestrian facilities is discussed. The interrelationships among facility characteristics and the various levels of impacts on pedestrians, motorists, abutting property occupants, and the community in general are presented.

An approach to general economic cost estimating in terms of both construction cost and continuing operating and maintenance costs is described. Several means of converting these costs to a figure useful in comparing facilities and evaluating benefits are given.

17. Key Words	18. Distribution Statement
Pedestrians, Pedestrian Facilities Urban Planning Cost/Benefit Analysis	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	75	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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I. INTRODUCTION

BACKGROUND

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 the pedestrian is often at the mercy of the motorist, the rights of pedestrians have declined. In many present day environments, coexistence to a pedestrian 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 providing separate pathways, and at times, entirely 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 most developed form to date in the pedestrian mall (typified by many suburban shopping malls), but it is also found in the closing and conversion of vehicular streets 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.

Highway engineers and urban planners tend to differ in their reasons for applying vertical separation. The highway engineer's primary concern with separation is as a tool with which he can improve the 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 highway engineers almost universally ignore pedestrian movement. Urban planners, who often mention the relief of vehicular congestion as a benefit of separation, prefer to emphasize the freedom and pleasant surroundings available to pedestrians. The highway engineer introducing a pedestrian bridge over a heavily travelled highway is not only eliminating a potential source of vehicle delay, but is also 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.

PURPOSE

This manual is intended for 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. Specifically, it addresses the means of evaluating the costs and impacts of pedestrian facilities. An attempt has been made to go beyond the more basic elements of movement to identify, delineate, and quantify the factors that influence pedestrian movement, pathway choice, and facility utilization. For facility costs, specific cost contributing factors are identified. Particularly significant is the structured breakout of those costs that 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.

USE OF THE MANUAL

This manual is intended to provide the engineer or planner with guidelines on planning a pedestrian facility. It has been carefully prepared to enumerate all of the factors that should be taken into consideration when determining the need for a facility and the design a facility should have to best serve all people potentially affected by it.

This manual does not provide facility design specification; 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.

Additional information on many of the topics presented in this manual is contained in a companion technical report prepared by PMM&Co. and RTKL Associates Inc. entitled, *A Comparison of Costs and Benefits of Facilities for Pedestrians.*[1]

ORGANIZATION OF THIS MANUAL

Chapter 2 presents some basic considerations about pedestrian trip making and pedestrian flow. The basic characteristics of pedestrian trips that should be considered when planning pedestrian facilities are discussed. Finally, the pedestrian walkway system as an abstract circulation system is presented.

Chapter 3 describes the basic types of separate pedestrian facilities, including the general concepts of separation. Each type of horizontal-, vertical-, and time-separated facility is described and relevant advantages and disadvantages of each are discussed.

Chapter 4 discusses the types and nature of the impacts that separate pedestrian facilities have on various categories of users and nonusers. First, the importance of considering the interactions among facility attributes and impacts is delineated. Then the impacts of facility attributes on users are detailed. Finally, the impacts on nonusers—motorists, abutting property occupants, and the community in general—are discussed.

Chapter 5 presents a general approach to developing the full economic cost of facilities. Methods for developing both the initial cost and the continuing costs are discussed and means of reducing these to a single, comparable economic cost are presented.

II. PEDESTRIAN TRIP GENERATION, ATTRACTION, AND CIRCULATION

The extent to which pedestrian facilities are used depends on whether or not they:

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

The first factor relates primarily to the volume of pedestrian trip exchange, and the second factor addresses pedestrian pathway choice in terms of safety, comfort, and convenience.

FACTORS INFLUENCING PEDESTRIAN TRIP EXCHANGE

The volume of pedestrian trip exchanges that will be generated, attracted, and circulated between a given origin and destination depends on four elements:

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

The type of land use associated with a given origin and destination greatly determines the type of pedestrian trips that will be generated, and attracted, (i.e., department stores are associated with an entirely different subset of pedestrian trips than high schools). The number of trips attracted and generated by an activity is usually dependent on its size and type (i.e., large retail stores attract and generate more trips than small retail stores; a large office building more than a small office building). Accessibility of a destination from an origin helps determine trip exchange (i.e., if a destination is too far to walk, takes too long, or requires an inordinate amount of energy, the trip may not be made at all, or an alternate mode of transportation may be used.)

An understanding of trip exchange elements is especially important to the planning of facilities for successful utilization. One element that must be considered is that many grade-separated pedestrian systems involving retail activity depend on the ability to attract shoppers from at-grade competition. In order to be successful, these shopping centers must first attract pedestrians by their type and size. The inducement to make a change in grade must be strong. Another element that must be considered is that the separated activity must provide several easily accessible means for making a change in grade level. Clearly, a few small shops that can be reached only by stairs are not likely to attract many trips.

PEDESTRIAN TRIP CHARACTERISTICS

Trip purpose is closely related to the type of land use associated with pedestrian trip attraction, and generation. Different land uses create different types of trips, and trip purpose is the essential concept that links activity centers together. Table 1 classifies pedestrian trips by the following three purposes:

- *Terminal Trips* — All trips made to and from home and points 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 those trips—personal and business trips, employee lunch trips, most kinds of shopping trips—for which walking is merely a means to achieving the end (i.e., arrival at the destination).

- *Recreational Trips* — Trips made for the purpose of pleasure. This category includes trips to theatres, sports events, and social activities, and other trips—for which walking itself is one of the primary purposes of the trip.

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* — Non-terminal trips that are made in conjunction with work (e.g., trips to other buildings for meetings) or as a part of work (e.g., police foot patrols or delivery services); and

- *Personal Business Trips* — Which can be further classified as:

  - *Shopping Trips* — Non-terminal trips made for the purpose of purchasing a product of retail personal service (e.g., trips to pick up dry cleaning, trips to restaurants), and

  - *Service Trips* — Non-terminal trips made for the purpose of obtaining personal services (e.g., trips to a doctor, dentist or lawyer's office).

TABLE 1

TRIP PURPOSE

Kind of Trip	Purpose of Trip
Terminal	mode transfer
Functional	business (e.g., work, delivery) personal business shopping (e.g., primary, employee, incidental, lunch) services (e.g., to doctor, dentist, lawyer)
Recreational	exercising cultural social sightseeing

Within the general category of personal business trips, the subcategory of shopping trips is further subdivided into:[2]

- *Primary Trips* — Shopping trips made by persons whose sole purpose is making a purchase;
- *Incidental Trips* — Shopping trips made by persons who have another primary trip purpose and incidentally shop;
- *Lunch Hour Trips* — A special category of shopping trips made mostly by office workers and similar employees to restaurants and cafeterias during lunch hour; and
- *Employee Trips* — Shopping trips made by employees who shop before work, after work, or during lunch hour.

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

An understanding of the various purposes of pedestrian trips can facilitate the effective design of pedestrian facilities through an examination of the needs of trips for various purposes, and the factors which influence the pdestrian's choice of routes. The more functional the trip, the greater the need for directness and minimizing effort. The more recreational the trip, the greater the need for pleasant surroundings and protected environment. Such considerations should be identified and included in the design of a pedestrian system.

THE PEDESTRIAN SYSTEM

In this manual, the term "pedestrian system" is restricted to the physical environment in which the pedestrian walks. 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 the concept of the pedestrian circulation system is readily apparent in the urban core, it is just as applicable to surburban areas. In fact, the pedestrian circulation system can be described as a network much like the vehicular circulation system is described in transportation planning.

One of the two basic elements in the pedestrian network is *the origin/destination* (node) of the walking trip. Nodes--centers of pedestrian activity, points of pedestrian concentration, and attractors and generators of pedestrian trips--are classified as two basic types:

- *Primary (or terminal) Nodes* -- Locations associated with mode transfer where the basic walking trip begins and ends (e.g., parking areas, transit stops, residences); and

- *Secondary (or activity) Nodes* -- Locations other than primary that attract trips from the primary nodes as well as from other secondary nodes (e.g., offices, stores, restaurants).

The second basic element in the pedestrian network is the series of *linking pathways.* For this manual, the pathways will be divided into two categories:

- *Vehicle-Dominant* -- Pathways that exist in or alongside space dominated by vehicular movements; and

- *Pedestrian-Dominant* -- Pathways that are reserved exclusively for pedestrian movement except for the possible intrusion of emergency vehicles.

Table 2 is an ordered listing of pedestrian system terms and serves to illustrate the relationships between the terms.

The primary example of the vehicle-dominant pathway system is the parallel grid pattern of ordinary sidewalks that has grown out of years of common use of streets and roadways by vehicles and pedestrians. To the traveller, whether on foot or in a vehicle, this system

TABLE 2
PEDESTRIAN SYSTEM TERMINOLOGY

Element	Examples
Node	
Primary (terminal)	transit stops (e.g., bus, train, subway)
	parking areas
	residential concentrations
Secondary (activity)	offices
	retail stores
	restaurants, theaters,
	vertical access points (e.g., stairs, ramps, escalators, elevators)
	pathway intersections
Links	pathways, walkways
Vehicle-dominant	sidewalks
	crosswalks
Pedestrian-dominant	horizontal separations
	vertical separations
	time separations

offers a coherent network of familiar paths and landmarks. 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, personal safety is jeopardized every time he must cross a vehicle pathway, longer trips are necessitated because his path is forced into the parallel grid structure, and air and noise pollution and visual and physical obstruction caused by vehicles must be endured.

However, separate, or pedestrian-dominant pathways can yield benefits to both the pedestrian and the motorist. Facilities such as separate walkways crossing above or below vehicular pathways can provide safe, convenient, and comfortable environments for the pedestrian and can free the motorist 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 stores that abut the pedestrian paths. Within this manual, an inventory of various facilities designed specifically for pedestrian movement is provided and discussed.

III. PEDESTRIAN FACILITIES

Pedestrian systems can be defined by the manner in which pedestrians and vehicles are separated. The three elements of separation are horizontal, vertical, and time. The first two elements are usually incorporated into the structures of pedestrian facilities, while the third is usually implemented within the context of existing vehicle-dominant pathways (e.g., the "all walk" phase of traffic signals, the temporary closing of streets for exclusive pedestrian use as malls).

Horizontally or vertically separated elements may be used alone 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 either horizontal or vertical elements or both, in various combinations. Most systems implemented in large urban centers contain both types of elements. In this manual, representative types of separation are discussed. The discussion centers around the list shown in Table 3, which is an overview of the numerous ways in which pedestrian and vehicular traffic can be separated.

HORIZONTAL SEPARATION

The two primary types of horizontally separated systems are:

- *Parallel* — systems that accommodate pedestrian movement immediately adjacent to, at grade, and parallel to vehicular movement; and

- *Displaced* — systems that are located away from the vehicle network and accommodate pedestrian movement along pathways that are independent of vehicular pathways.

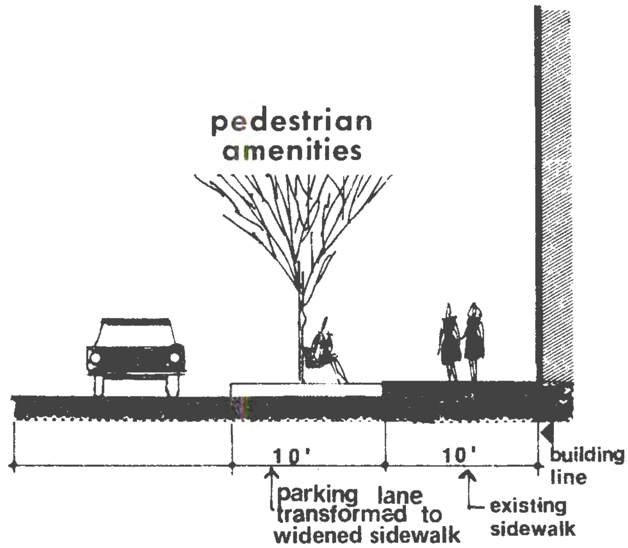
Parallel Elements

The most basic parallel element is the *ordinary sidewalk.* Improvements to sidewalk systems include widened sidewalks, partial malls, and arcade setbacks. *Sidewalks may be widened* (Figure 1) by transforming existing parking lanes into added sidewalk space. Plantings, benches, and other pedestrian amenities can serve as separators between pedestrian and vehicular movement. *Partial malls,* in which most but not all vehicular traffic is excluded, are simply a more complete treatment of widened sidewalks. Nicollet Mall, (a *partial mall*) in downtown Minneapolis, limits vehicular intrusion to buses and taxicabs, although through

TABLE 3

ELEMENTS OF SEPARATION OF PEDESTRIAN AND VEHICLE SYSTEMS

Element	Examples (Implementation)
Horizontal Separation	
Parallel elements	sidewalks widened sidewalks partial malls setback arcades
Displaced elements	displaced sidewalk grids full malls street closings (except temporary)
Vertical Separation	
Below-grade elements	tunnels under highways subwalks, subways, tunnels under CBD
Above-grade elements	bridges over highways skyways, skywalks, elevated and second-level systems within CBD classified as: independent independent-flanking integral-flanking integral interior
Time Separation	"all walk" phase of traffic signals temporary street closings
Connectors	stairs ramps escalators elevators



Advantages

- Increases sidewalk space and relieves pedestrian congestion in areas of high volume
- Reduces potential for conflict and accident by providing buffer zone
- Reduces annoyance of vehicle noise and fumes
- Eliminates visual obstruction of parked autos
- Increases space for pedestrian amenities

Disadvantages

- Reduces width of street available for vehicle use
- May increase vehicle congestion on surrounding streets
- Does not solve the problem of conflict at intersections
- Does not affect pedestrian exposure to weather

FIGURE 1: SIDEWALK WIDENINGS

vehicular traffic is allowed on all streets perpendicular to the mall. Partial malls have most of the advantages and disadvantages of sidewalk widenings, except that transit service to shoppers and workers in the area is improved by excluding other vehicles. The concept of *arcade setbacks* which can be applied during both original construction or remodeling, involves recessing the building abutting the sidewalk in order to create additional pedestrian space (Figure 2). This method provides the advantages of sidewalk widening, while maintaining the original roadway width, and provides a partial cover from inclement weather.

Displaced Elements

The two basic elements of displaced systems are:

- *Full malls* – characterized by excluding all vehicular traffic; and
- *Displaced grids* – characterized by locating the sidewalk system within the block instead of its perimeter.

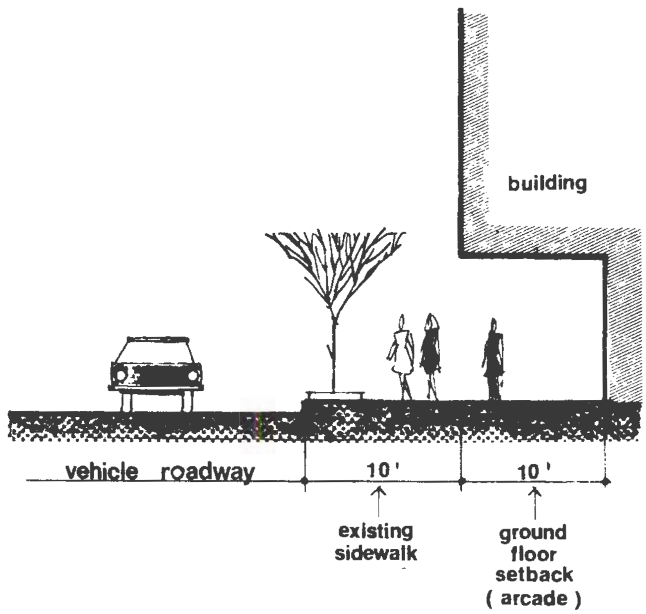
Full malls (Figure 3) are probably the best known examples of horizontal pedestrian-vehicular separation. They usually occur when a main shopping street is closed to all but emergency vehicles; traffic may be allowed on all, some, or none of the cross streets within the mall area. Time separation (temporary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

Displaced grids (Figure 4) can be created by converting alleys into pedestrian spaces and then opening the backs of shops abutting the alleys so that the store backs become the store fronts. Displaced grids may also be formed by shopping arcades or lobbies within the interior of office buildings or hotels.

VERTICAL SEPARATION

The three primary elements of vertical separation are:

- *Below-grade* – Systems in which the vehicular movement is above and the pedestrian movement is below in tunnels or underground concourses;
- *Above-grade* – Systems in which the pedestrian movement is above in skyways, elevated or second-level walkways, and pedestrian bridges, and the vehicular movement is below, at-grade level; and
- *At-grade* – Systems in which the vehicular movement is directed either above or below pedestrian movement that is maintained at-grade. Because of the expense involved, such separations are usually only accomplished when there is some other reason to remove vehicular traffic from grade level.



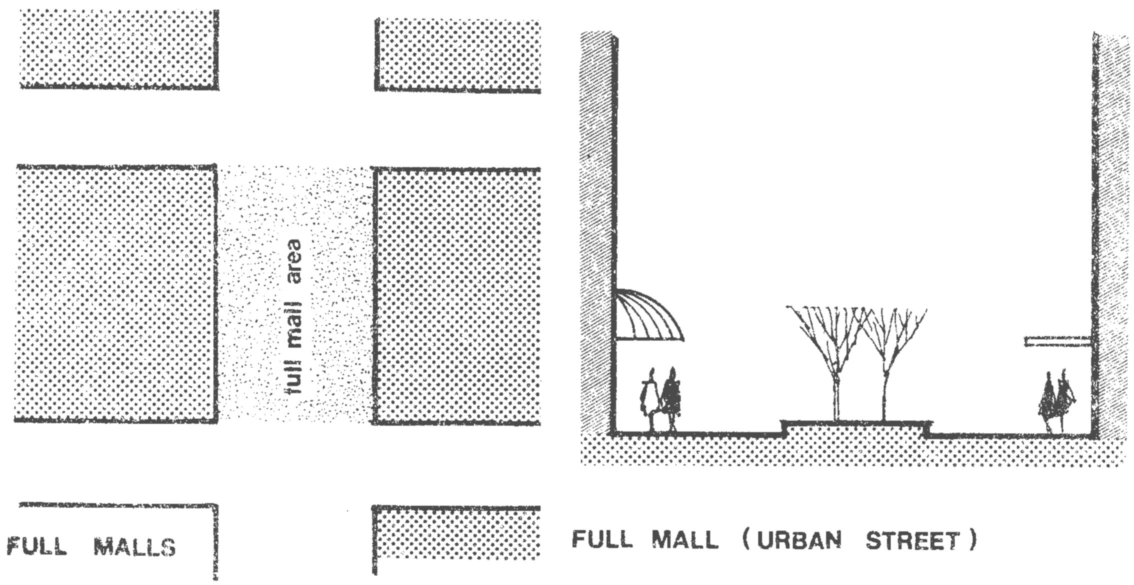
Advantages

- Relieves pedestrian congestion
- Reduces potential for conflict and accident by use of buffer zone
- Reduces annoyance from vehicle fumes and noise
- Increases space for pedestrian amenities
- Provides 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



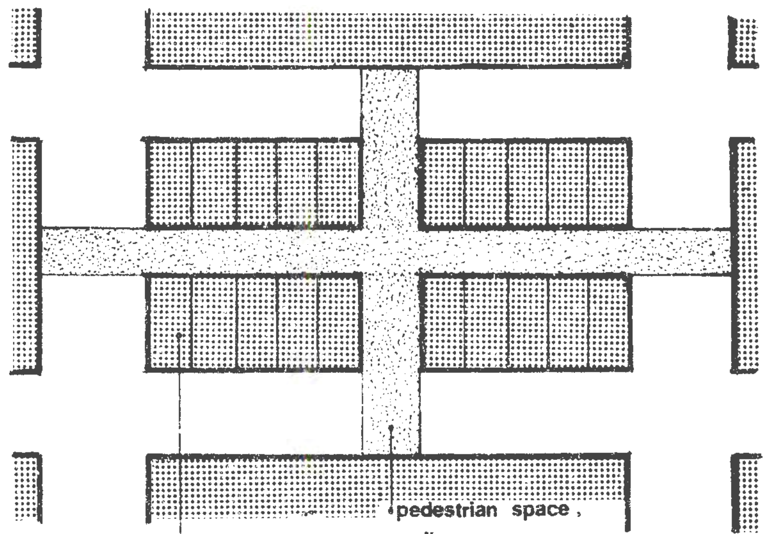
Advantages

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

Disadvantages

- Requires 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
- Tends to reduce retail activity on nearby streets
- May create legal problems with property lines, etc.
- May require extensive utility upgrading

FIGURE 3: FULL MALLS (URBAN STREETS)



Advantages

- Eliminates potential for conflict associated with parallel grid
- Facilitates servicing of retail activities with backs to street
- Gives pedestrians direct access to both sides of walkway
- Provides freedom from vehicle noise, fumes and visual obstructions
- Relieves pedestrian conflict at intersection for vehicular turning movements and simplifies driver attention requirement
- Can provide shelter

Disadvantages

- May require midblock 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 midblocks crossings are not signalized
- Requires extensive remodeling when incorporated into existing buildings

FIGURE 4: HORIZONTALLY DISPLACED GRIDS

Below-grade systems have been utilized in several cities in Canada, the United States, and Europe. This solution is often implemented when existing subterranean systems (e.g., subway stations) can be converted to pedestrian use. Above-grade systems include a wide variety of elevated skyways and are often implemented when conditions warrant separation, but the expense of depressing the walkways or elevating the streets is prohibitive. One of the best known elevated systems is the skyway system of midblock connections in Minneapolis. At-grade systems are usually constructed as part of some highway improvement program, for example The Mall in Washington, D.C., where much of the cross-mall traffic has been diverted underground for aesthetic reasons, which also permits freer pedestrian movement. Tables 4 and 5 contain listings of the advantages and disadvantages of above- and below-grade systems.

Below-Grade Elements

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

- Cut-and-cover; and
- Tunneling.

Cut-and-cover construction, especially in downtown areas, can severely affect traffic flow. Either the traffic must be detoured during the entire period, causing delays to motorists and loss of revenue to merchants, or temporary decking must be installed, which is expensive and still causes some delay and inconvenience.

Above-Grade Elements

Above-grade elements (Figure 5 thorugh 8) are classified into five basic types:

- independent;
- independent-flanking;
- integral-flanking;
- integral; and
- interior.

In addition, classification sub-levels can be defined based on materials, construction type, and extent of covering.

At-Grade Elements

Two basic classifications of At-grade systems are:

- highway over; and
- highway under.

Because the facilities are primarily highway rather than pedestrian and the justification for their construction is usually primarily outside the pedestrian system, they will not be discussed further in this manual. However, many of the impact considerations are the same as discussed in this report.

The use of a particular type of facility or combination of types depends to a large extent upon the physical characteristics of the existing buildings and rights-of-way and upon the concensus of the adjacent land owners. The impact of above-grade construction also depends upon the characteristics of existing facilities, but it can usually be constrained to be less disruptive than construction of below-grade facilities.

TIME SEPARATION

The basic element of time separation is the temporary closing of vehicle facilities for the exclusive use of pedestrians. In its simplest form, the "all walk" phase of traffic signals, vehicle-pedestrian conflict is eliminated by converting an intersection to pedestrian use for some short period of time. A more comprehensive conversion involves the temporary closing of a street during store hours to facilitate access by shoppers. In such instances, stores are serviced during night hours when the street is again available for vehicle use.

TABLE 4

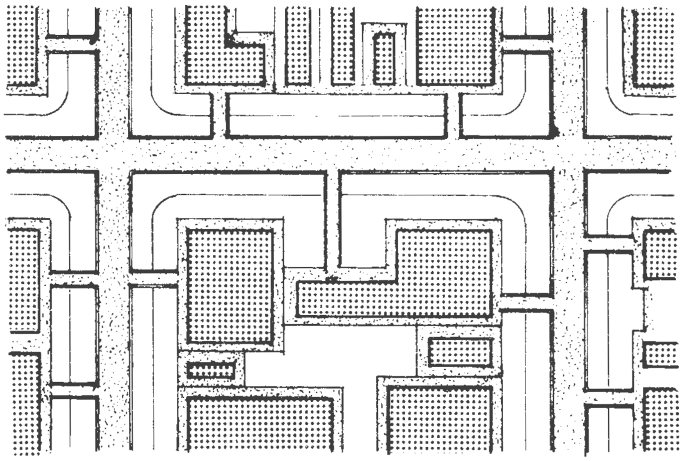
ADVANTAGES AND DISADVANTAGES OF BELOW-GRADE SYSTEMS

Advantages	Disadvantages
• Separates pedestrian movement from vehicular movement • Provides built-in protection from sun and inclement weather • Creates new parallel grid pattern • Maintain an unobstructed city-scape • Can be built in increments • Can be readily included in new construction • Provides direct linkage to existing underground systems • Provides direct linkage between major activity centers • Improves at-grade vehicular circulation	• Extremely expensive to construct • Requires change-in-grade and numerous entry points • Causes difficulties in linking new and old buildings • Causes loss of visual contact with city resulting in feelings of disorientation • Creates an articificial environment • Presents potential security problems • Makes emergency servicing difficult

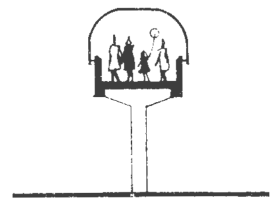
TABLE 5

ADVANTAGES AND DISADVANTAGES OF ABOVE-GRADE SYSTEMS

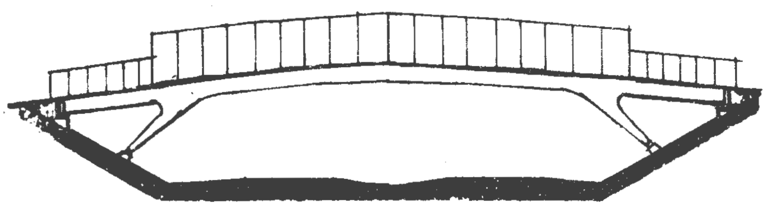
Advantages	Disadvantages
• Separates pedestrian movement from vehicular movement	• Expensive to construct
• Can provide more direct, convenient paths for pedestrians	• Requires change-in-grade and numerous entry points
• Provides elevated visual vantage point for user	• Causes difficulties and expense to connect to existing development
• Provides direct linkage of major activity centers	• Could diminish retail activity at the street level
• Can be built in increments and expanded into comprehensive system	• Requires coordination of property owners, which may be difficult to achieve
• Can be readily included in new construction	• Contains structural elements which form areas at-grade that present security problems
• May utilize public rights-of-way linking and/or passing through existing buildings	• Can be difficult to coordinate with 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	• Makes emergency service difficult



SKYWAY SYSTEM OVER STREET RIGHTS · OF · WAY



Independent



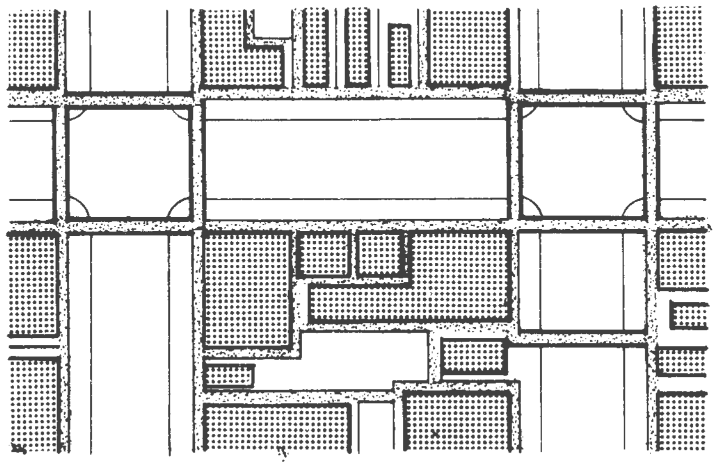
ELEVATION

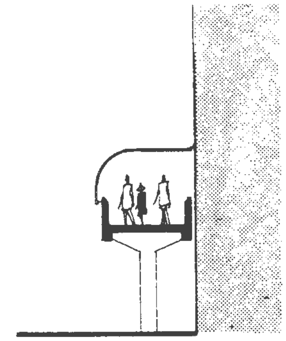
PEDESTRIAN BRIDGE OVER MAJOR ARTERY

Elevated Walkways (Independent)

These elements are structurally self-supporting and freestanding. They occur primarily at street crossings parallel to public rights-of-way and at pedestrian bridges over major arterials.

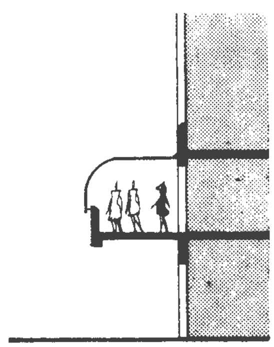
FIGURE 5: INDEPENDENT ELEVATED WALKWAY





Elevated Walkways (Independent-Flanking)

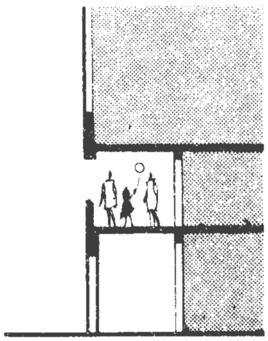
This system is defined by those portions of the walkway which are structurally self-supporting and adjacent to (flanking) building facades. This kind of system is usually constructed above sidewalks along public right-of-ways and adjacent to existing buildings at the second-level. In those systems, the walkway is usually tied to existing structures at second-level lobbies and, in the case of enclosure, the walkway enclosure bonnet is received by the facade of the existing structures.



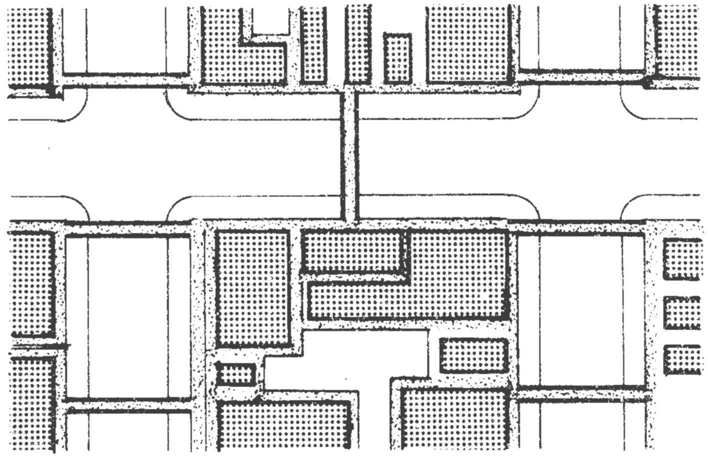
Elevated Walkways (Integral-Flanking)

This system is defined by those portions of the walkway which are structurally integral with and located along the building facade outside of the building envelope of new building developments. In this system, 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: ELEVATED WALKWAYS—INDEPENDENT-FLANKING AND INTEGRAL FLANKING



Integral

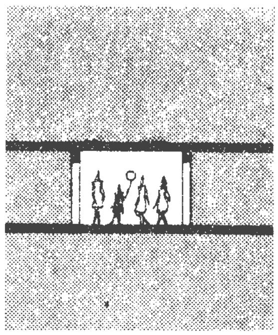


WALKWAY SYSTEM INCORPORATED WITHIN BUILDING PERIPHERIES

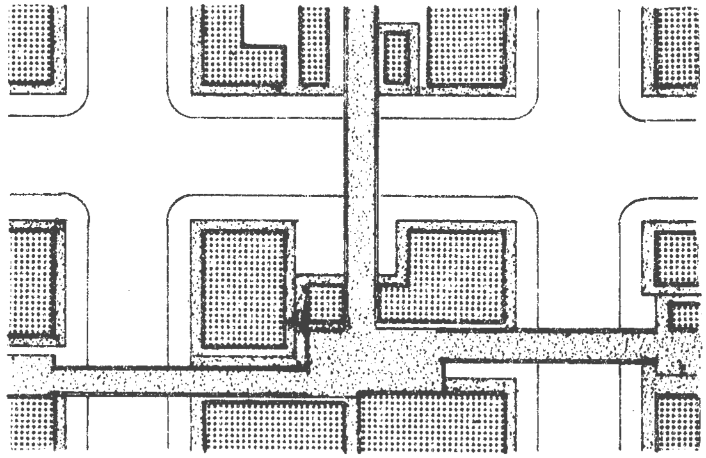
Elevated Walkways (Integral)

This system is defined by those portions of the walkway which are structurally integral with and located along the building envelope of new building developments along the walkway network. In this system the walkway is planned, designed, and built as part of the new development.

FIGURE 7: INTEGRAL ELEVATED WALKWAY



Interior



WALKWAY SYSTEM WITH MIDBLOCK CONNECTIONS

Elevated Walkway (Interior)

This system is defined by those portions of the walkway which are located within the interior of new developments and/or existing buildings 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: INTERIOR ELEVATED WALKWAY

IV. FACILITY IMPACTS

The establishment of separate facilities for pedestrian circulation has several real and potential impacts on both facility users and non-users. The real impacts are a direct result of the facilities' characteristics and can be measured by the changes the facility has on its environment. The potential impacts are only realized if the facility is extensively used.

Three levels of impacts of pedestrian facilities can be identified. The *first-order impacts are those experienced by the pedestrians* who use the facilities. These are the causative factors inducing people to use or avoid them. Utilization of facilities gives rise to a series of secondary impacts. These *second-order impacts are those experienced by others directly affected* by changes in pedestrian circulation patterns (e.g., motorists and occupants of abutting properties) and can only be realized if the first-order impacts are sufficient to change pedestrian circulation. A third level of impacts may also occur if the impacts at the first two levels are sufficient. *Third-order impacts are those experienced by the locality* in the forms of increased property tax revenue from higher property values, demands for parking, and provisions for security.

INTERACTION OF FACILITY DESIGN AND IMPACTS

The extent of the impacts depends upon the interaction among these elements:

- Design attributes of the facility;
- Utilization of the facility;
- Magnitude and nature of first-order impacts;
- Magnitude and nature of second-order impacts; and
- Magnitude and nature of third-order impacts.

The interrelationships among the elements are diagrammed in Figure 9. Solid lines represent strong relationships; dashed lines represent potential feedback.

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. These elements include the accessibility of activity centers, the directness and continuity of pathways, and the pedestrian amenities. As shown in Figure 9, the design attributes influence the extent to which facilities are used by pedestrians. If facilities are not used, their impact may be minimal; if they are used to a great extent, they give rise to benefits to pedestrians in the forms of increased safety, convenience, and comfort. Pedestrian benefits (i.e., first-order impacts) can induce second-order impacts for nonusers, such as increasing the retail sales of owners of abutting property and decreasing the delay of users of vehicles.

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. Impacts may be both positive and negative. Beneficial impacts are more likely to generate a positive feedback, reinforcing other facility impacts and inducing additional utilization. Merchants, enjoying improved patronage from a facility are likely to improve their establishment, attracting more patrons, and so forth. Negative impacts usually inhibit use of the facility, primarily by discouraging pedestrians or secondarily by removing the reasons for making trips. Merchants, experiencing poor patronage, will close shop, further discouraging pedestrians from coming to other shops. Both positive and negative impacts should be considered in facility design and a feedback mechanism should be present as pedestrian facilities are expanded or upgraded.

The interaction among the 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 benefit accrues to him, from the facility, and thus secondary benefits cannot be realized. Therefore, as diagrammed in Figure 9, *the process has to start with a design that stimulates pedestrian utilization in order to achieve the resultant benefits.*

The benefit that separate pedestrian pathways can offer pedestrians must be distinct and easily recognized. Facilities must offer the pedestrian *directness* which will not result in time loss or greater distance. The pathways must provide *continuity* of movement and possess adequate *capacity*. Vertical change requirements must be minimized, and adequate vertical assistance must be provided where changes must be made. *Protection* against wind, rain, cold, heat, and pollution will encourage utilization, as will the provision of *security* against criminal threat. The *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 do not negate any benefits. Adequate *accessibility* to the pathways should be provided. Lastly, the pathway should offer *aesthetic* interest to stimulate pedestrians and psychologically reduce the negative effects of trip length and vertical change.

Steps can be taken where appropriate, to encourage use of pedestrian facilities and to discourage use of alternative routes. A prime example is the use of barriers to prevent pedestrians from crossing at-grade in the vicinity of pedestrian overpasses and underpasses.

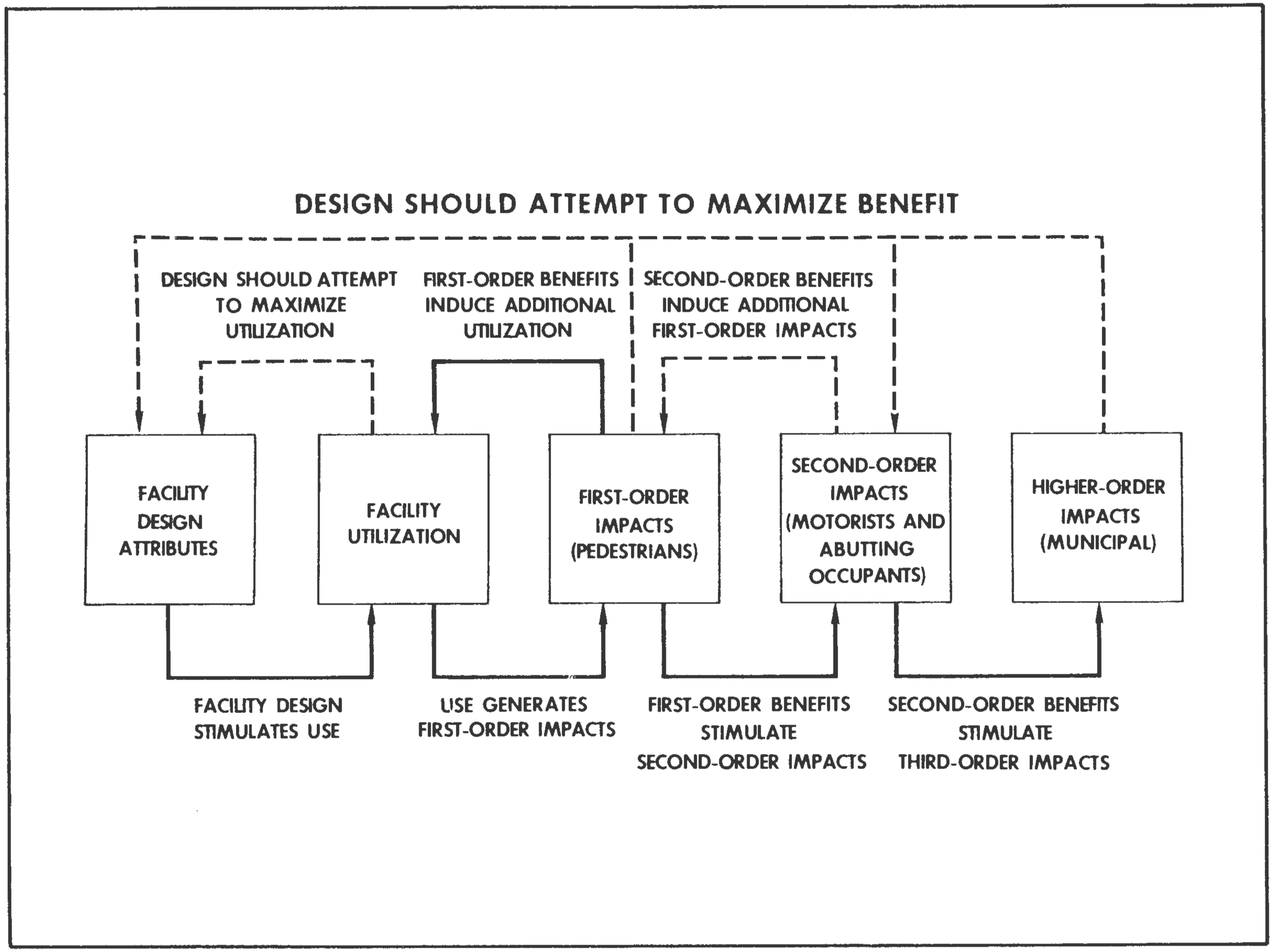


FIGURE 9: PEDESTRIAN FACILITY IMPACT DIAGRAM

Such countermeasures are likely to decrease pedestrian benefits while increasing vehicle benefits. In fact, if the negative impacts are so great as to discourage walking or cause pedestrians to select alternative routes, the benefits of a pedestrian facility may disappear.

IMPACTS ON PEDESTRIANS

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 may be realized. Facilities should be conceived, planned, and implemented to overcome the impedances to walking as perceived by the pedestrian himself.

As shown in Table 6, the pathway attributes of a pedestrian facility are directly related to the 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.

TABLE 6

RELATIONSHIP BETWEEN PEDESTRIAN BENEFITS AND PATHWAY ATTRIBUTES

Pedestrian-Related Impacts	Facility Pathway Attributes
Safety	Separation
Convenience	Directness Continuity Capacity Availability
Comfort and Others	Protection Coherence Security Interest

The attributes listed are not necessarily independent of one another. For example, a coherent pathway provides comfort in that it relieves the anxiety of the lost or confused pedestrian; but, it may also avoid backtracking and delay resulting from direction finding that could accompany being lost, and in this way it impacts on pedestrian convenience. System accessibility is tied to the convenience of having alternative paths, but it can 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 attribute should be treated as a separate entity.

Safety and Separation

Despite the pedestrian's general disregard for his safety, pedestrian safety is universally accepted as one of the primary benefits of pedestrian/vehicular separation. It is quoted as an objective, usually the primary objective, of separation in nearly all of the literature dealing with the subject. Consequently, the planner must consider the magnitude of the safety problem, the relative accident risks, and the potential impact on safety of each pedestrian facility and of the system as a whole.

There is little question that the conflict between pedestrians and vehicles is a serious problem. The number of deaths resulting from this conflict is again on the rise after reaching a minimum in the late 1950's. In 1971 alone, 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 vehicle-related deaths was a pedestrian.[3]

In urban areas, pedestrian deaths exceed all other motor vehicle-related types of accident.

Accident Risk

The probability of being involved in an accident is 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. Despite the problems associated with measuring exposure, much research has been conducted on the relationship between relative risk and accident causal factors. (Reference 4 provides for a compilation of the scope of these efforts.) A list of the factors considered is shown in Table 7.

TABLE 7

GENERAL CAUSAL FACTORS IN PEDESTRIAN ACCIDENTS

Pedestrian Factors	Environmental Factors
• Age	• Time of day
• Sex	• Day of week
• Physical and mental limitations	• Location
• Location familiarity	• Street type
• Driving experience	• Street width
• Movement relative to vehicle	• Lighting, illumination
• Presence of alcohol or drugs	• Weather conditions
• Crossing volumes	• Crossing type (uncontrolled, etc.)
• Visibility to drivers	
• Socio-economic status	
Driver Factors	**Vehicle Factors**
• Age	• Speed
• Sex	• Type
• Presence of alcohol or drugs	• Condition
• Physical and mental limitations	• Traffic volumes
• Driving experience	• Movement relative to pedestrian

Safety Impact of Separation

Providing facilities that separate pedestrian and vehicular movement tends to reduce pedestrian risk. The risk is decreased to the extent of the pre-existing risk (i.e., that associated with the crossing point prior to facility construction) and in proportion to the extent that the facility is 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. If the pedestrian chooses not to use the facility, the crossing risk remains approximately equal to the preexisting risk at the crossing point. The combined conditions of risk in the presence of a grade-separated facility is:

R_A = pedestrian risk associated with a specific crossing;

= 0 if facility is utilized for crossing;
= R_B if facility is not utilized for crossing.

For numerous pedestrian crossings the average risk incurred per crossing will be the risk 0 and R_B, weighted by the *extent of utilization*, to give:

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

$$= U \cdot 0 + (1 - U) \cdot R_B$$

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

The absolute risk reduction is given by:

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

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

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

$$= U \cdot R_B$$

Hence, risk reduction is directly related to facility utilization and preexisting 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.

Cost of Pedestrian Accidents

A recent preliminary report by the National Highway Traffic Safety Administration (NHTSA)[5] places the estimated average loss per fatality resulting from a motor-vehicle accident at $200,700. The estimated average loss per nonfatal injury is placed at $7,300. These figures cover all motor vehicle-related accidents. Two sources (6,7) estimate the probability of a pedestrian accident per crossing in urban areas to be about 0.5×10^{-6}. While the specific circumstances surrounding each facility should be considered, using this estimate, the average accident cost per pedestrian crossing a street is approximately $0.01 or $1.00 per 100 crossings.

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.

Pedestrian convenience should first be examined within the context of pathway impedance – the extent and cost of delays to pedestrians by vehicles. Convenience then should be considered 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.

Pathway Impedance

Most able-bodied people will make short trips on foot. The added mobility alone often makes walking the most convenient means of transportation 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 10, which represents a composite of walking trip surveys in the centers of a number of cities.

As shown in the figure, the desire to walk distances greater than a few hundred feet decreased rapidly. A pedestrian over-crossing 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 the 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 realizes the attendant benefits.

The curve in Figure 10 is for illustration only. In most cases, the application of the kind of information depicted is partly determined by the way in which the relationship is altered by such factors as trip purpose, location, pedestrian age, and so on. While even the smallest saving in distance 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 purposes of illustration, distance is certainly not the only variable in decision of whether or not to walk. Certain alternative equidistant paths may be characterized by different walking times, which 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 pathway will influence the pedestrian's propensity to walk. While not necessarily independent of each other, all the factors act as impedances to walking and to the walking trip.

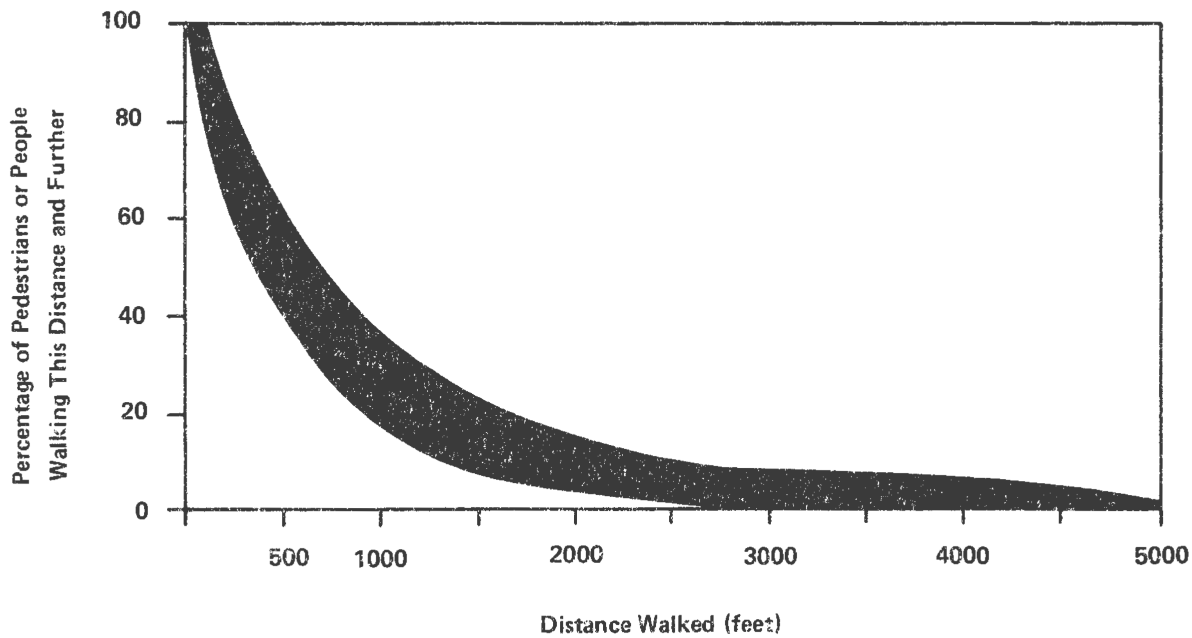


FIGURE 10: RANGE OF WALKING DISTANCES FOUND IN CITY CENTERS

Source: Reference (8).

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

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

The cost of delay depends 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. Here, 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 empirical results(1) to be about 15 seconds per crossing. 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(9) 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 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

= $1.36 per 100 crossings

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

Convenience and Pathway Attributes

Although it is a threat to safety and represents an impedance to pedestrian movement, vehicle flow is not the only element that impedes a pedestrian's 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 as having the lowest level of impedance. The major attributes impacting upon his convenience are directness; continuity; capacity; and availability.

Directness

Directness is a measure of pathway impedance related to the time, distance, or effort required to use a pathway connecting two given points and is used to describe the extent to which a pathway deviates from the most direct alternative pathway. When a pathway offers the pedestrian a savings in time, distance or effort, it is more apt to be used than one that requires additional effort, even when the latter provides a safer route.

Continuity

Continuity is a pathway attribute that expresses the extent to which a given pathway between two points is interrupted by obstacles (e.g., vehicular conflicts, vertical changes, turning movements, directional decision points) which add not only to the pathway impedance but also to the distance between the points. Continuity 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. If a path has numerous turns, it 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. Turns and decision-making introduce impedances to continuous pedestrian movement. Vertical movement usually requires more time and energy than horizontal movement without the same reduction in trip length. To effect a change in grade where space permits, ramps are preferred to stairways since they are safer and easier to use.(8) 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, and then stairs.

Capacity

Pathway capacity is an essential factor influencing pedestrian movement and convenience, and in turn, facility utilization. If capacity is inadequate, pedestrians become crowded together, movement is impeded, walking speed is slowed, trip time is increased, 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 is enhanced by the pedestrian's own perception of the pathway's benefits.

Availability

The two major elements of pedestrian facility availability are:

- Facilities should be available when they are needed.
- 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 (e.g., links through interior arcades), 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 security problems. Nevertheless, wherever 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.

Comfort and Other Impacts

From the point of view of the pedestrian, walking is affected by many other factors that cannot be classified as safety or convenience. When asked to rank factors that discourage walking, respondents ranked crime first, followed by unfavorable weather.(3) Numerous other factors such as pollution, lighting, and health were also noted in varying degrees of importance. 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. Four additional major factors should be considered:

- security;
- environmental protection;
- coherence; and
- interest.

Obviously, the pedestrian 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.

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.[10] 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.[3]

Maintaining security is often cited as the main problem with pedestrian underpasses. It appears that long pedestrian tunnels (e.g., highway underpasses and subway passageways) 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 sight lines to exterior centers of activities.

If walkways are to be designed for 24-hour use (e.g., connectors to train stations, subways, other terminals, and to a lesser extent to late-night activities such as theaters, restaurants, and hotels), then it will be necessary to give special attention to providing adequate security. Sight lines to other centers of activity should be carefully considered, lighting should be used to discourage criminal acts, and adequate surveillance and policing should be provided.

Environmental Protection

People view unfavorable weather as second only to crime as a factor that discourages walking. A cover or closure will encourage walking by providing pedestrians with the comfort and benefit of some degree of climate control. Obviously, the provisions 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. Unlike other modes of travel where the vehicle affords protection from the elements, the facility must provide protection to the pedestrian. Environmental protection is important for several reasons:

- Pedestrians naturally desire protection from environmental extremes.
- Retail shopping activities of pedestrians can be affected by the weather.
- Risk of accident increases in inclement weather.
- Protection against extremes in weather can also improve the pedestrian environment with regard to noise and air pollution.

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, a coherent system (i.e., one that is 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.

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 the surrounding buildings and other land uses that 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. Consequently, when he is transferred into a totally pedestrian domain such as an extensive below-grade walkway system, the pedestrian loses much of his orientation.

Within a pedestrian facility, the familiar grid pattern may be modified to achieve more efficient linkages between activity centers, and the pedestrian's 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.

The potential for anxiety, disorientation, and confusion of the pedestrian will cause him to forsake the benefits of the facility for the familiarity of the sidewalk. To alleviate these undesirable possibilities, 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:[1]

- information;
- direction;
- assurance; and
- confirmation.

Considering the pedestrian trip from origin to destination, the point of entry should provide the pedestrian with *information* which orients him within the pathway system (e.g., a "YOU ARE HERE" type of graphic layout). Using a uniform set of terms and graphics, the locations of access and grade change, public conveniences, telephones, as well as streets, buildings, and well-known landmarks close to the facility should all be noted. *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, and so on; where this has not been done, it is confusing. During his trip, the pedestrian should have assurance 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. The physical layout should be free of ambiguity and should have paths that are as direct as possible. 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. Redundancy is helpful for assuring and confirming, and trail blazes are useful elements of signing for providing direction, assurance and confirmation of a route.[12] Lastly, if the space is inherently incoherent, the need for signing increases, thus causing a decrease in sign effectiveness.[13] 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.

Interest

The implementation of separate pedestrian systems offers 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. The amount of interest that exists along a pathway can have a direct influence on pedestrian route choice, trip lengths, and times. In the extreme, recreation environments provide comfortable, safe, lively, and varied pathways that induce walking trips.

People's attitudes toward downtown environments as expressed when presented with photographs of various components such as buildings, people, foliage, overhead wires, street paving, sidewalk paving, amount of sky, and signs 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-configurations; a considerable amount of foliage; and few if any signs."(14)

While this seems to be in disagreement with the commonly felt need for more urban open space, it supports the view expressed by one planner 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.(15)

IMPACTS ON MOTORISTS

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.(16,17) 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. Several efforts which have addressed these delays are discussed in the following sections.

Signal Controlled Intersections

In general, two distinct intervals occur during each green phase where pedestrian crossings restrict and delay right-turn vehicular movement. For heavy pedestrian flow (i.e., 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 followed rather abruptly by an interval of much weaker conflict characterized by fewer stopped vehicles and less vehicle delay resulting from fewer pedestrians in the crosswalk. Table 8 shows 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 9.

The complex relationship between total vehicle delay and factors such as queue lengths, vehicle flows, and pedestrian volumes was examined using a simulation model approach calibrated to the data collected on intersections. The results obtained are shown in Table 10, which shows the relative delay as a function of vehicles per hour, pedestrian flows, and percent or right-turning vehicles; the value for 800 vehicles per hour with 10 percent turning right and no pedestrian flow was set to a value of 1.00.

TABLE 8

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

<table>
<tr><th rowspan="2">Pedestrian Flow (peds/hr)</th><th colspan="9">Time Elapsed Since Start of Phase (Seconds)</th></tr>
<tr><th>5</th><th>10</th><th>15</th><th>20</th><th>25</th><th>30</th><th>35</th><th>40</th><th>Over 40</th></tr>
<tr><td>0 - 200 (light)</td><td colspan="9">←WEAK→</td></tr>
<tr><td>201 - 500 (moderate)</td><td colspan="2">←STRONG→</td><td colspan="7">←WEAK→</td></tr>
<tr><td>Over 500 (heavy)</td><td colspan="5">←VERY STRONG→</td><td colspan="4">←WEAK→</td></tr>
</table>

Source: Reference (18).

Uncontrolled Crossings

The impact of pedestrian crossings at uncontrolled intersections or other crossing points varies considerably with the nature of the highway and its locality. In some areas, the requirement that drivers yield to pedestrians is strongly enforced, while in other locations, pedestrians must fend for themselves. Consequently, the delay to both vehicles and pedestrians is very difficult to determine in any general sense. One relationship between vehicle delay and

TABLE 9

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

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.

Source: Reference (18).

TABLE 10

RELATIVE VEHICULAR DELAY

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
1,200	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

Source: Reference (14).

pedestrian movement for uncontrolled crossings in urban areas where yielding to pedestrians is enforced is given by:[18]

D = total vehicle delay (in hours)

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

where:

P = pedestrians crossing per hour,

Q = vehicle flow per hour, and

V = traffic speed in miles per hour.

The above equation is 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 (e.g., weather, speed limits) may act to significantly modify the empirical equation presented here.

However, it is clear that the pedestrians do 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.

The Cost of Vehicular Delay

The nature of vehicular travel time and its attendant costs (i.e., those costs related to vehicle operation and ownership and to the value of driver and passenger time) has received a considerable amount of attention.[19] While vehicle-related costs have been isolated and established with a reasonable degree of detail and certainty, per car-hour values for the travel time of the driver plus some estimated number of persons per vehicle remains an elusive factor. This difficulty not withstanding, it would be of value to obtain a gross estimate of the cost of vehicle delay caused by crossing pedestrians for comparison with the cost of pedestrian accidents and the cost of pedestrian curbside delay.

For vehicle delay time, Winfrey[19] 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[20] who suggests a value of $2.82 per person per hour, and of Lisco[7] 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:

$$(\$3.25) \times \frac{260}{3,600} = \$0.23.$$

Based on the same set of assumptions of 1,000 vehicles per 100 pedestrians the vehicle-related operating cost can be estimated as[1]:

$2.47 per 1,000 vehicles per 100 pedestrians.

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

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

Although the uncertainty associated with this estimate is apt to be great, it appears 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.

IMPACTS ON ABUTTING PROPERTY

Land Use and Private Sector

In measuring the impact that a pedestrian facility has on abutting property, one must consider the changes that usually begin long before the facility is implemented. A baseline set of measures should be developed prior to implementation. For comparison, a second set should be taken after an initial adjustment period when the novelty has worn off. It would be desirable to measure the specific effects attributable to the facility to isolate them from the effects of changes in acitivites in surrounding areas. Then, only the appropriate net impacts would be attributed to the facility.

Assuming these measurements can be made, the examination of facility impacts on abutting properties would focus on 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 Table 11. 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 retail areas outside the CBD. Several caveats are necessary when estimating

TABLE 11

MEASURE OF FACILITY IMPACT UPON ABUTTING PROPERTY AND ITS OCCUPANTS

To Determine the Impact on	Measure Changes In
Land-use 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 retail sales • Average shopper expenditure • Reinvestment of retail-related capital into permanent improvement, or operation • Retail operating hours • Volume and/or quality of inventory • Extent of advertising and promotion • Property ownership patterns • Extent of effective trade area • Level of merchant association activity

impacts on abutting property. The success of a pedestrian system or facility is dependent upon 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. The creation of a system which simply transfers retail activity from one location to another does not result in a net benefit to retailers. A pedestrian facility would have to stabilize a decreasing trend in property values and retail sales in order to represent a positive impact. It is important to realize that a few indicators of success are not necessarily sufficient without a careful examination of the entire urban system.

Servicing Considerations

Another major impact of pedestrian systems on abutting property relates to the servicing of the properties and the distribution of goods. The implementation of a grade-separated facility provides the opportunity to develop an improved system for servicing and distribution. However, unless adequate solutions are implemented, negative impacts on abutting properties will result from the facility. For example, if servicing concepts are treated as a system as important as any other, a complete horizontally and vertically separated trucking and delivery arrangement can be designed. Extensive treatments such as this may not be possible in most cases because of the limits of development involved in the facility project. The removal of links in the street system, which can then be used for servicing, is an alternative treatment of this problem.

HIGHER ORDER IMPACTS

In the overall impact structure, pedestrian facilities—depending on extent—have the potential to effect higher order impacts (Table 12). While many of these impacts can be expressed in numerical terms, only a few can be evaluated monetarily. When dollars can be assigned, the problem remains one 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 impacts, spheres of influence, net effects, and similar difficulties. It is usually difficult to draw tight borders around a specific facility in terms of overall benefits and costs to a city.

In addition, benefits (increased employment) result mainly from the synergism of other effects; while some of these effects can be considered to be a result of the walkways, many other factors are usually acting simultaneously. Isolating the contribution of one factor is almost impossible.

The realization of many of the benefits shown in Table 12 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, increased tax revenues accruing to the city may be reduced by the need for added services, so that the net effect of total

TABLE 12

POTENTIAL HIGHER ORDER FACILITY IMPACTS

Kind of Impact	Way Realized
Financial	Net increased tax revenue from existing sources Stabilization 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

benefit is lessened. While it is useful to be aware of these potential impacts while planning a facility, only those which can be clearly identified as resulting from the planned pedestrian facilities can usually be included quantitatively in a plan. Table 12 lists the potential higher order facility impacts.

V. FACILITY COSTS

AN APPROACH TO FACILITY COSTING

Pedestrian facility costs are a function not only of the type of facility but also of site-specific, geographic, and time-dependent factors. In the approach described in the following paragraphs, 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 purpose of cross-comparison and 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.

Suggested unit costs and quantities for estimating facility construction and operating and maintenance costs are presented in Reference 1. These costs must be carefully adjusted according to the procedure outlined below to be valid. Wherever possible, use of actual local costs is preferable since the values presented in Reference 1 are general averages for national experience and can only be approximately adjusted for local variation and different years.

The approach presented here can further serve as a technique for evaluating or assessing the overall cost of competing alternative facility types. The cost approach is shown in Figure 11, which illustrates a framework for estimating costs for a particular project. There are five basic steps in developing a total cost estimate. These steps, which are described in more detail later, are as follows:

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.

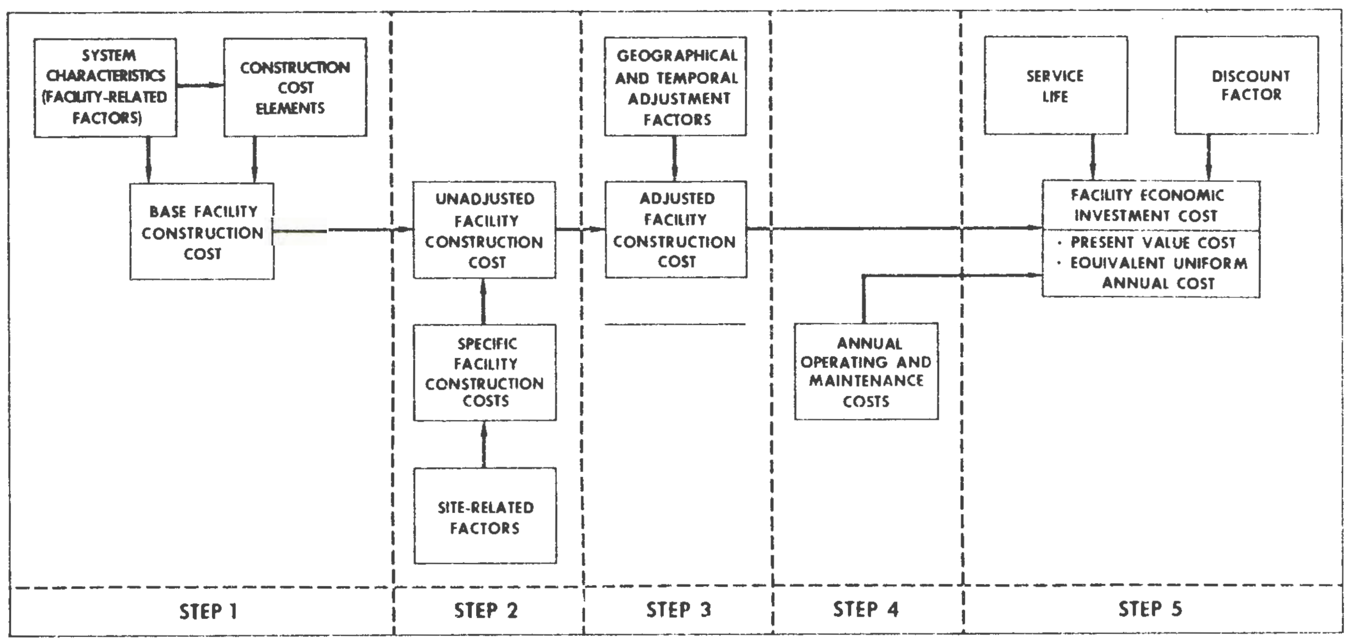


FIGURE 11: FACILITY COSTING APPROACH

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 costs are 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 is 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, costs are best computed using specific information for each proposed facility.

Step 5: Two basic and equivalent methods are presented for reducing both the current investment costs of construction and the future costs streams for facility operation and 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 the overall facility cost. In general, comparisons between alternative systems or between costs and benefits are valid only after Step 5 has been completed, so that costs can be considered to be on a comparable basis. 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 the material used or type of enclosure system provided, and

- site-related factors which reflect characteristics of the facility location such as the extent of utility relocation or traffic interruptions required.

These two sets of factors are used to develop two costs which, when combined, constitute the unadjusted facility construction cost. 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 relates to cost elements that change from site to site and, in general, have to be redetermined for each situation.

CONSTRUCTION COST COMPONENTS

The first three steps in the procedure presented above are used to develop an estimate of the construction costs for a facility. The three basic considerations in developing a construction cost estimate are:

- facility characteristics;

- site characteristics; and

- geographic and temporal adjustments.

The cost components associated with each of these are discussed in this section.

Facility-Related Construction Cost Components

The facility construction cost, unadjusted for any effects of time or geographical location and disregarding costs specifically related to the site or site preparation, is 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 measures) and

- the number of construction units (i.e., square feet, lineal feet), which is consistent with the unit cost figure.

Both the unit cost and the number of units are functions of several other factors:

- facility type;

- dimensional properties;

- structural properties;
- material and construction method;
- enclosure system; and
- sub-elements.

Facility Type

Base construction costs will obviously vary with the type of facility (because type affects the unit cost of construction) and with the dimensions of the facility (since dimensions determine the number of construction units). Specific types of facilities are discussed in Chapter 3; for the purpose of costing, the following generic 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 of a specific facility determine the number of construction units and influence structural support costs and several of the specific site-related costs. The important structural properties to be addressed for above-grade facilities are:

- length of clear span; and
- method of facility support (superstructure).

The per unit construction cost of a section of a facility will increase as a function of the length of clear span. 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. Six general systems of materials and construction methods for above-grade facilities are presented below:

- *Steel*—prefabricated steel truss members—assembled off site, delivered to the site, and subsequently erected; including, by definition, vierendeel (vertical and horizontal members only) or conventional triangulation systems.

- *Steel*—standard steel construction—(steel rolled and shop fabricated) all connections and joinings erected in place on site.

- *Concrete*—cast-in-place—uses conventional reinforced framing for concrete to be cast-in-place on site; includes beam and slab, one-way joists, or waffle construction systems.

- *Concrete*—precast—prestressed members and piers are prefabricated off site and delivered to the site for erection; includes by definition, single or double "T" sections up to 65 feet long by 8 feet wide.

- *Concrete*—cast-in-place—post-tensioned, high-strength strands stressed to place the concrete in compression prior to the application of service loads.

- *Composite construction*—steel and concrete used together; normally performed in-place of site.

There are also other systems that 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.

Principal methods of construction of below-grade facilities are:

- *Cut-and-cover*—a method of construction that involves partially removing (cut) the roadway surface to allow for the construction of the underpass, subsequently replacing (cover) it, then returning the roadway to normal operation; and

- *Tunnelling*—a method of construction that involves burrowing beneath the roadway right-of-way with no alteration to the roadway surface during the course of construction.

The method of construction and materials used in malls are more a function of the surrounding facilities, the condition of the existing right-of-way, and of the architect's choice than they are of the general characteristics of the facility type. No detailed breakdown will be included here.

The costs of each of these combinations depends upon the availability of both material and construction expertise for each of the options. A secondary level of cost-influencing factors may have to be considered if either of these resources is limited. 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., pre-fabricated steelwork).

Enclosure System

The type of enclosure and mechanical support system 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 — covered but not enclosed from the weather; and
- enclosed — fully enclosed and employing one of three types of climate control—naturally ventilated, heated only, or heated and air conditioned.

Sub-Elements

This last group of factors includes those miscellaneous elements (lighting, signing and landscaping) that impact on the base cost. 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, comparing them and estimating their cost and impact is difficult. Where it is necessary to include these sub-elements, careful and detailed consideration of their cost impact should be analyzed.

Site-Specific Construction Cost Components

The construction cost of a facility often depends 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 paragraphs where the intent was to examine the base construction cost component that are 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, rather an attempt has been made to detail those variables that tend to dominate or greatly influence total construction cost. For example, those components, such as the cost of traffic delays during construction, which are often overlooked in economic analyses of proposed facilities, have been included. In addition, because it would not be practical to provide point estimates of various site-related costs due to their associated variance, some values are given as reasonable ranges. The following factors are discussed in subsequent sections:

- foundation conditions;
- utilities relocation;
- terminal connections;
- structural considerations; and
- traffic delays during construction.

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 results in additional costs due to the inherent unusual construction requirements. Where poor soil conditions exist, below-grade facilities are not always feasible.

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, electricity, telephone) 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 and can contribute up to 200 percent to base construction costs. The possibility of routing below-grade walkways to avoid utilities should be considered. In one city, 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.[21]

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 has been identified in Figure 12, including stairs, ramps, elevators and escalators. The selection and use of any or all of these connectors is contingent upon several factors:

- the total vertical difference between the elevation of the system at the point of desired accessibility;
- pedestrian volumes at the access and egress portals;
- type of node in terms of activity linkage;
- the capacity characteristics in terms of volumes of pedestrians through an area in a given period of time; and
- population characteristics considering proportion of elderly and 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.

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.

Structural Considerations

Several structural considerations, namely distance spanned and method of support, were addressed in the development of base facility costs. The consideration and selection of a structural system is also contingent upon several locational factors, such as the following:

- length to be spanned unsupported;

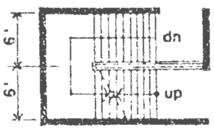
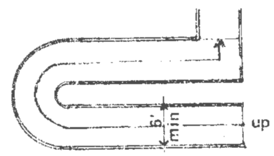
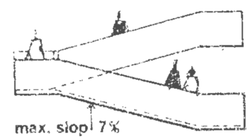
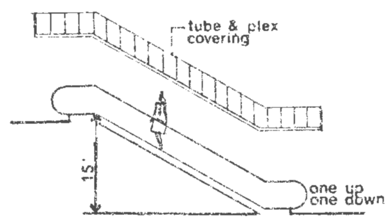
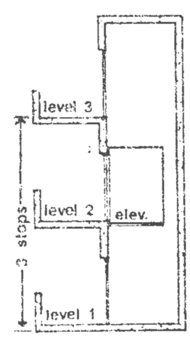
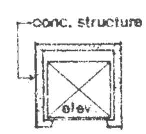
Connection	Description
Stair	 Plan  Section Width of run is 6 feet; connect grade to 15 feet minimum.
Ramp	 Plan  Section Width of run is 6 feet; connect from grade to 15 feet minimum; maximum slope is 7%.
Escalator	 Section One pair (up/down) from grade to 15 feet.
Elevator	 Section  Plan One cab (capacity 3000 lbs.) to stop at three levels.

FIGURE 12: TYPICAL TERMINAL CONNECTIONS

- feasibility of locating intermediate pier supports in medians within the road right-of-way; and

- compatibility of the structure with ambient environmental and architectural characteristics.

For 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 impedence 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.

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 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 depends 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 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 performed at an off-site location, 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 13 provides a simple relationship between the type of material/construction and the time required to erect it on-site. The actual extent of construction delays depends on numerous other factors, but all things being equal, the impact of the construction technique employed is as shown.

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

Geographical and Temporal Adjustments

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

Geographical Differences

Construction costs vary from region to region throughout the United States as a result of material supply characteristics, available labor, and unavailable 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.

TABLE 13

COMPARATIVE TIME TO ERECT FACILITIES
ON-SITE VERSUS CONSTRUCTION TECHNIQUE

Type of Construction Technique	Time Required To Erect Facility On-Site Less Time/More Time			
	1	2	3	4
Prefabricated steel truss	(X)			
Standard steel construction		(X)		
Cast-in-place, concrete		(X)		
Cast-in-place, concrete prestressed			(X)	
Precast concrete	(X)			
Composite steel and concrete			(X)	
Concrete or steel arches				(X)

The *Dodge Manual for Building, Construction Pricing and Scheduling, 1973,* (22) 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.

Temporal Differences

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 know inflation factors to get comparable costs. Possible sources of this information are the *Engineering News-Record's (ENR) Construction Cost Index, and the ENR Building Cost Index.*

CONSTRUCTION COST ESTIMATES

Specific unit costs for components used to estimate facility construction cost should be obtained locally where possible to avoid geographic adjustments and to ensure the availability of materials and expertise for the type of construction desired. This section provides a formula for integrating the component unit costs in the final facility cost estimates. The general unit costs in the report "*A Comparison of Costs and Benefits of Facilities for Pedestrians*" can be used if no other source is available; however, they should be used with the cautions outlined in that text.

Computation of Base Construction Cost

The equations for computing the base facility construction costs for the facility types examined are given in Figures 13 through 16. Distribution of costs for full and partial malls are outlined briefly in Table 14 and explained in more detail in the above mentioned report. 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, care should be taken to make the appropriate allowances for these special features. The summarized breakdowns in Table 14 are useful for more general estimating purposes.

TABLE 14

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

Cost Attributed To	Percent of Total Cost for Partial Mall	Percent of Total Cost for Full Mall
Site preparation	5.8	4.8
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

$$C_U = \text{Base Construction Cost of Highway Overpasses}$$

$$= \left[\sum_{\substack{\text{All}\\ \text{spans}}} \begin{pmatrix}\text{Length of}\\ \text{span in}\\ \text{lineal}\\ \text{feet}\end{pmatrix} \times \begin{pmatrix}\text{Cost per lineal}\\ \text{foot (depending}\\ \text{on material, con-}\\ \text{struction, span}\end{pmatrix} \right]$$

$$+ \left\{ \begin{pmatrix}\text{Total facility}\\ \text{length in feet}\end{pmatrix} \times \left[\begin{pmatrix}\text{Cost per lineal}\\ \text{foot of drainage,}\\ \text{if applicable}\end{pmatrix} + \begin{pmatrix}\text{Cost per lineal}\\ \text{foot of lighting,}\\ \text{if applicable}\end{pmatrix} \right] \right\}$$

$$+ \left[\begin{pmatrix}\text{Cost}\\ \text{per}\\ \text{pier}\end{pmatrix} \times \begin{pmatrix}\text{Number of}\\ \text{piers}\\ \text{required}\\ \text{See Note 1}\end{pmatrix} \right] + \left[\begin{pmatrix}\text{Cost}\\ \text{per}\\ \text{median}\end{pmatrix} \times \begin{pmatrix}\text{Number of}\\ \text{medians}\\ \text{required}\\ \text{See Note 2}\end{pmatrix} \right]$$

Note 1: The number of piers required is [2 x (no. of spans)].

Note 2: The number of medians required is (no. of spans -- 1).

FIGURE 13: COMPUTATION OF THE BASE CONSTRUCTION COST FOR HIGHWAY OVERPASSES

$$C_U = \text{Base Construction Cost of Street and Highway Underpasses}$$

$$= \left[\begin{pmatrix}\text{Length of facility}\\ \text{in feet}\end{pmatrix} \times \begin{pmatrix}\text{Cost per linear foot}\\ \text{depending on condition}\end{pmatrix} \right]$$

FIGURE 14: COMPUTATION OF BASE CONSTRUCTION COST FOR STREET AND HIGHWAY UNDERPASSES

C_S = Base Construction Cost for Conventional Steel and Concrete Elevated Walkways

$$= \left[\sum_{\text{All spans}} \left(\begin{array}{c} \text{Length of} \\ \text{span in} \\ \text{feet} \end{array} \right) \times \left(\begin{array}{c} \text{Cost per lineal foot} \\ \text{depending on material,} \\ \text{construction and span} \end{array} \right) \right]$$

$$+ \left[\left(\begin{array}{c} \text{Total} \\ \text{length of} \\ \text{facility in} \\ \text{feet} \end{array} \right) \times \left(\begin{array}{c} \text{Cost per lineal foot} \\ \text{of enclosure system} \\ \text{depending on type} \end{array} \right) \right]$$

$$+ \left[\left(\begin{array}{c} \text{Cost} \\ \text{per} \\ \text{pier} \end{array} \right) \times \left(\begin{array}{c} \text{Number of} \\ \text{piers required} \\ \text{See Note} \end{array} \right) \right]$$

Note: Number of piers required is [2 x (no. of spans)].

FIGURE 15: COMPUTATION OF BASE CONSTRUCTION COST FOR CONVENTIONAL STEEL AND CONCRETE ELEVATED SKYWAYS

C_S = Base Construction Cost for Street Trussed Skyways

$$= \left(\begin{array}{c} \text{Facility} \\ \text{area in} \\ \text{square feet} \end{array} \right) \times \left(\begin{array}{c} \text{Cost per square} \\ \text{foot depending on} \\ \text{enclosure condition} \end{array} \right)$$

FIGURE 16: COMPUTATION OF BASE CONSTRUCTION COST FOR STEEL TRUSSED SKYWAYS

Unadjusted Facility Construction Cost

The unadjusted facility construction cost is the base cost of construction plus the costs of site contingencies. If a 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 17, will be called the facility construction cost, or simply construction cost.

Geographically Adjusted Construction Cost

Use of the *Dodge Manual* locality adjustment factors is illustrated in Figure 18. If local unit costs are used, this adjustment will not be necessary. If only partial local unit costs are used, this adjustment should be applied to those costs obtained from other sources.

Construction Costs Adjusted for Time

The use of inflation factors is given in Figure 19. If historic costs are being brought up to date, the ENR cost indices can be used. If future costs are being estimated, a rate of construction cost inflation must be estimated. Here again, the ENR indices can be useful for projecting future trends.

OPERATING AND MAINTENANCE COSTS

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

- facility physical design properties;
- user group characteristics (e.g., shoppers, commuters);
- degree of direct accessibility by maintenance crews;
- proximity of the facility to other publicly maintained areas (whether the facility can be maintained as part of a larger maintenance area);
- ownership of the facility (public or private);
- type of security required; and
- extent of enclosure of the system.

$$C = \text{Unadjusted Facility Construction Cost (or Construction Cost)}$$

$$= \left(\begin{matrix}\text{Base cost of} \\ \text{facility} \\ \text{construction}\end{matrix}\right) + \left(\begin{matrix}\text{Specific costs of} \\ \text{site contingencies}\end{matrix}\right)$$

FIGURE 17: DEFINITION OF FACILITY CONSTRUCTION COST

$$\frac{C_A}{F_A} = \frac{C_B}{F_B} = \text{Base Cost}$$

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 for Location A, compute:

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

FIGURE 18: USE OF THE DODGE LOCALITY CONSTRUCTION COST ADJUSTMENT FACTORS

To find the cost in year X, when the cost in year Y is known, compute:

$$C_X = \text{Cost in year X}$$

$$= \frac{\text{(factor for year X)}}{\text{(factor for year Y)}} \text{(cost in year Y)}$$

FIGURE 19: USE OF THE ENR BUILDING COST INFLATION FACTORS

Facilities such as pedestrian highway overpasses incur minimal O&M costs, primarily for lighting and some annual maintenance. Large-scale systems 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 15.

The maintenance cost curve begins to rise sharply with the age of the structure, especially during the last quarter of its projected life span, and proceeds until 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 (walkways, overpasses), however, do not contain major mechanical systems, and therefore do not represent an accelerated maintenance cost curve. Since maintenance costs remain relatively constant with increases reflecting only the rising costs of labor and materials attributed to normal inflation, they will not be examined for these types of facilities.

THE ECONOMIC COST OF A FACILITY

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 streams of expenditures for system operation and maintenance occur over the future years in which the facility is in service. However, since money has a time-dependent value (that makes an amount now on-hand worth more than an equivalent amount at some future time), in terms of their "present value", future expenditures are of lower value than more current expenditures.

TABLE 15

PERCENTAGE ALLOCATION OF O&M COSTS

O & M Category	Percentage Allocation
Taxes	25
Maintenance	26
Repairs	15
Utilities	14
Security	14
Miscellaneous	6
	100

Source: RTKL Associates Inc. estimates.

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 the costs and benefits that occur 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.

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 costs (assumed to be at its present value). The required computation is shown in Figure 20.

The present value computation in Figure 20 is expressed in its simplest form and assumes that the facility has zero salvage value at the end of its service life, and that the 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 values of N 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 21.

(PVC) = Present Value of Facility Costs

$$= \begin{pmatrix}\text{Adjusted facility} \\ \text{construction cost}\end{pmatrix} + \begin{pmatrix}\text{Present value} \\ \text{of O\&M costs}\end{pmatrix}$$

$$= \begin{pmatrix}\text{Adjusted facility} \\ \text{construction cost}\end{pmatrix} + \sum_{N}\left[\left(\text{PVF} \times \begin{pmatrix}\text{Annual uniform} \\ \text{O\&M costs}\end{pmatrix}\right)\right]$$

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 20: COMPUTATION OF THE PRESENT VALUE OF FACILITY COSTS

$$(PVB) = \text{Present Value of Annual Facility Benefits}$$

$$= \sum_{N} \left[(PVF) \times \begin{pmatrix} \text{Annual uniform} \\ \text{value of benefits} \end{pmatrix} \right]$$

Where (PVF) is as defined in Figure 20.

FIGURE 21: 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 22 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.

The Equivalent Uniform Annual Cost Method

This method will yield results that are essentially the same as 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 actual or proposed financing scheme. The basic computation is shown in Figure 23.

The benefit to cost ratio and net present value computed as shown in Figure 24 will yield the same result as that obtained using present value measures in Figure 22.

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 values of i and N.

$$(B/C) = \text{Benefits to Cost Ratio}$$

$$= (PVB)/(PVC)$$

---

or: $(NPV) = \text{Net present value of benefits over costs}$

$$= [\,(PVB) - (PVC)\,]$$

where: (PVC) is as computed in Figure 20, and

(PVB) is as computed in Figure 21.

FIGURE 22: COMPUTATION OF BENEFIT/COST RATIOS AND NET PRESENT VALUES OF ALTERNATIVES

$$(AC) = \text{Equivalent uniform annual facility cost}$$

$$= \begin{pmatrix} \text{Equivalent uniform} \\ \text{annual cost of} \\ \text{facility construction} \end{pmatrix} + \begin{pmatrix} \text{Annual uniform} \\ \text{O\&M costs} \end{pmatrix}$$

$$= \left[(CRF) \begin{pmatrix} \text{Adjusted facility} \\ \text{construction cost} \end{pmatrix} \right] + \begin{pmatrix} \text{Annual uniform} \\ \text{O\&M costs} \end{pmatrix}$$

where: $(CRF) = \text{Capital Recovery Factor}$

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

FIGURE 23: COMPUTATION OF THE EQUIVALENT ANNUAL FACILITY COST

$$(B/C) = \text{Benefit to Cost Ratio}$$

$$= \left(\begin{array}{c}\text{Equivalent uniform}\\ \text{annual facility cost}\end{array}\right) \Big/ \left(\begin{array}{c}\text{Annual value of}\\ \text{facility benefits}\end{array}\right)$$

$$= (AC)/(AB)$$

---

or: $$(NPV) = \text{Net Present Value of Benefits Over Costs}$$

$$= \left[(AB) - (AC)\right] (PVF)$$

where: (PVF) = The present value factor defined in Figure 20.

FIGURE 24: ALTERNATIVE COMPUTATION OF BENEFIT/COST RATIOS AND NET PRESENT VALUE OF ALTERNATIVES

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

The analysis tends to be most sensitive to values of N 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, is often difficult to estimate. The consideration of longevity 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,

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

however, are implemented within different financial frameworks where the object is not one of realizing a financial return. Most often they have an initial cost (e.g., for construction) 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, in an examination of 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 the abutting property conditions prior to determining a life cycle of each respective facility.

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