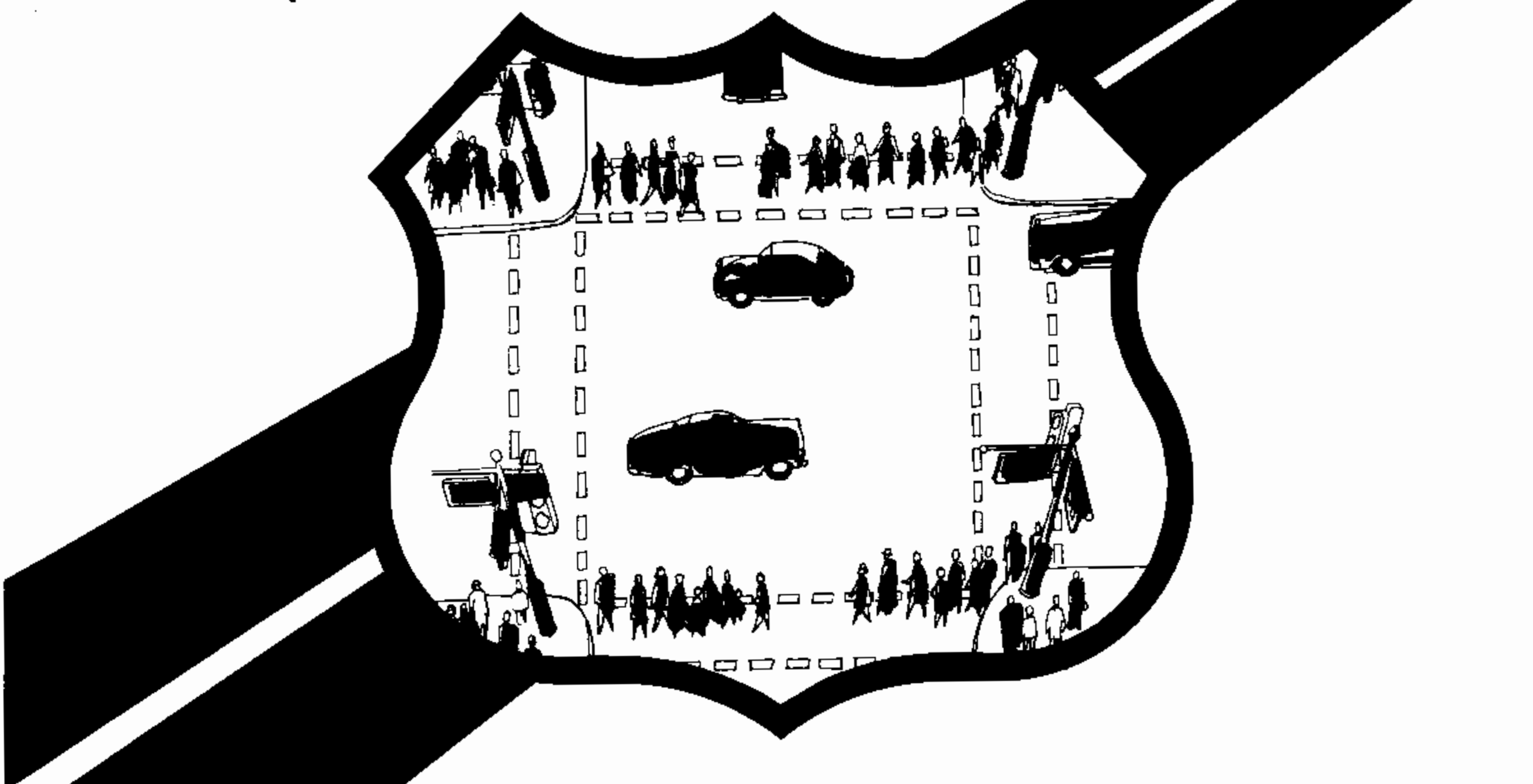
Report No. FHWA-RD-79-47

A PEDESTRIAN PLANNING PROCEDURES MANUAL

Vol. III. Technical Supplement

November 1978

Final Report



Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Environmental Design & Control Division
Washington, D.C. 20590

FOREWORD

This manual identifies the significant data, procedures and criteria that should be considered in the planning, selection and evaluation of both comprehensive pedestrian systems and individual facilities.

Research in pedestrian safety is included in the Federally Coordinated Program of Highway Research and Development as Task 1 of Project 1E, "Safety of Pedestrians and Abutting Property Occupants." Mr. John C. Fegan is the Project Manager from the Office of Research and Mr. Richard Richter is the Implementation Manager from the Office of Development.

Sufficient copies of Volume I are being distributed to provide a minimum of three copies to each regional office, five copies to each division office and ten copies for each State highway agency. Two copies each of Volume II and Volume III are being sent to the regional and division offices and five copies of each to the State highway agency. Direct distribution is being made to the division offices.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-79-47		

4. Title and Subtitle	
A Pedestrian Planning Procedures Manual Vol. III. Technical Supplement	5. Report Date November 1978 6. Performing Organization Code 8. Performing Organization Report No.
7. Author(s) L.S. Kagan, W.G. Scott, U.P. Avin	
9. Performing Organization Name and Address RTKL Associates Inc. The Village Square Village of Cross Keys Baltimore, Md. 21210 Kilkeary, Scott and Associates, Inc. 509 Powell Drive Annapolis, Md. 21401	10. Work Unit No. (TRAIS) FCP 31E042 11. Contract or Grant No. DOT-FH-11-8816
12. Sponsoring Agency Name and Address Office of Research Federal Highway Administration Department of Transportation Washington, D. C. 20590	13. Type of Report and Period Covered Final Report June 1975-November 1978 14. Sponsoring Agency Code

15. Supplementary Notes

FHWA Contract Manager: John C. Fegan, HRS-41

16. Abstract

The Manual identifies the significant data, procedures and criteria that should be considered in the planning and evaluation of both comprehensive pedestrian systems and individual facilities.

This volume explains the derivation of the data provided in Volume II and presents considerably more detailed data and methodologies for various tasks as well as worked examples. This material is supplemental to Volume II and is to be used in conjunction with it. This volume also provides the user with a fundamental understanding of the research underlying the development of the Process, allows him to examine its assumptions, and modify data to suit his specific conditions.

Other volumes in the series are:

Vol. No.	Report No.	Short Title
I	79-45	Overview
II	79-46	Procedures

17. Key Words	18. Distribution Statement
Pedestrian Planning Accommodations Safety	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	374	

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

PREFACE

The Pedestrian Planning Process is presented in three separate volumes.

VOLUME ONE

Volume One, the Overview, provides a general background and introduction to pedestrian planning and to the technical procedures of Volume Two. The major topic areas covered in this volume include:

The pedestrian planning context

- background
- the need for pedestrianization
- objectives of pedestrian planning
- relationship to land use/transportation planning

The need for a pedestrian planning process

- state of the art
- rationale for the process (utilization, benefits and impacts, pathway choice)

Overview of the Pedestrian Planning Process (PPP)

- major PPP phases (the demand modelling phase, the design and evaluation phase)
- description of the PPP tasks (brief overview of each task)

Application of the Pedestrian Planning Process

- objectives of the process
- using the procedures
- determining procedure(s) applicability

VOLUME TWO

Volume Two, the Procedures, is operational and sequential in nature. Each procedure within the Manual sets forth all the fundamental requirements for successfully conducting that specific aspect of pedestrian facilities planning, design and evaluation in terms of:

- Approach
- Data provided or required
- Specific methods of analysis or evaluation to be used
- Use and interpretation of output to aid in the decision-making process
- Relationship of specific procedures to the overall PPP

VOLUME THREE

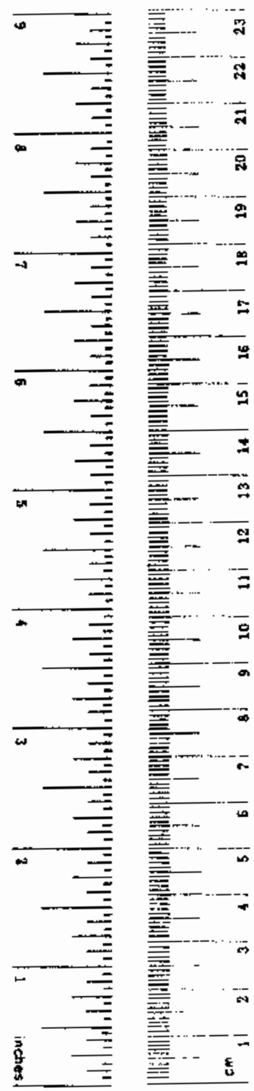
Volume Three, the Technical Supplements, explains the derivation of the data provided in Volume Two and presents considerably more detailed data and methodologies for various tasks as well as worked examples. This material is supplemental to the Procedures Volume and is to be used in conjunction with it. This volume also provides the user with a fundamental understanding of the research underlying the development of the Process, allows him to examine its assumptions, and modify data to suit his specific conditions.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

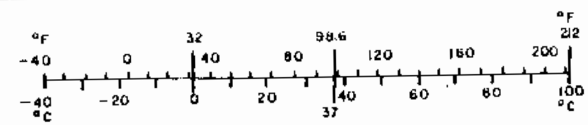


TABLE OF CONTENTS

SUPPLEMENT 1

DEFINITIONS OF CONCEPTS AND TERMS USED IN PEDESTRIAN PLANNING

1.1 The Pedestrian System Context

The purpose of the Pedestrian Planning Process is to provide a basis for the improved planning, design and evaluation of pedestrian systems. Although the concept of a pedestrian system can apply to all situations in which people walk, the particular focus of this manual is directed at those areas of robust, often intensive, pedestrian activity such as is found in most urban central business districts.

In its most simple form as illustrated in Figure 1-1, a pedestrian system consists of the interaction of three more elementary components:

- The pedestrian;
- The pedestrian environment;
- Other urban systems

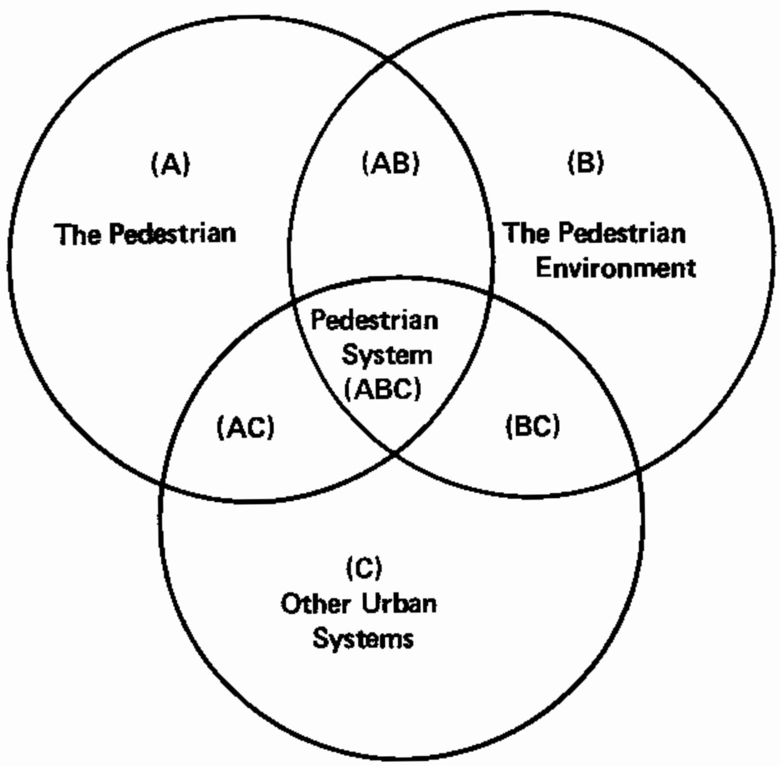


FIGURE 1-1

THE PEDESTRIAN SYSTEM
ELEMENTARY AND INTERFACE COMPONENTS

This interaction is often extremely complex in both content and scope. The system of interest might be a single sidewalk element, or it might be an entire urban area. In general, however, each elementary and secondary component shown in Figure 1-1 encompasses one or more considerations requiring attention within the pedestrian planning process. (For example, Figure 1-2 shows a typical interface between a pedestrian pathway and a traffic and transit right-of-way.) For example, typical questions related to each element in Figure 1-1 are:

The Pedestrian (A)

- What are the characteristics of the pedestrian tripmaking population?
- What are their perceived needs?

The Pedestrian Environment (B)

- What is the availability of current and future pedestrian space?
- What are the physical dysfunctions affecting pedestrian use of this space?
- How accessible are activity centers to each other via pedestrian movement?

Other Urban Systems (C)

- What are the current and projected land uses?
- What is the disposition of other urban transportation space?

The Pedestrian/Pedestrian Environment Interface (AB)

- What are the current and projected volumes and distributions of pedestrian tripmaking within the area?
- Is the capacity of existing pathways adequate to accommodate these volumes?

The Pedestrian Interface with other Urban Systems (AC)

- What are the major current and projected generators and attractors of pedestrian trips?
- What alternative transportation modes are available, or contemplated, for tripmaking?

The Interface Between the Pedestrian Environment and Other Urban Systems (BC)

- What are the space conflicts between pedestrian uses and other functions, and how can they best be resolved?
- Is the pedestrian interface with other system complementary?

The above list is not meant to be complete or operational, but is rather intended to highlight the nature of the issues related to the development of pedestrian systems. A successful pedestrian system requires the complex resolution of a further synthesis of these, and other, questions; that is, the (ABC) component in Figure (1-1).

In the following sections, individual elements of a pedestrian system are discussed in detail. The intention of these discussions is to provide the conceptual and definitional basis required to understand and utilize the procedures subsequently presented. The reader may choose to merely skim those discussions which are familiar, or reasonably understood.

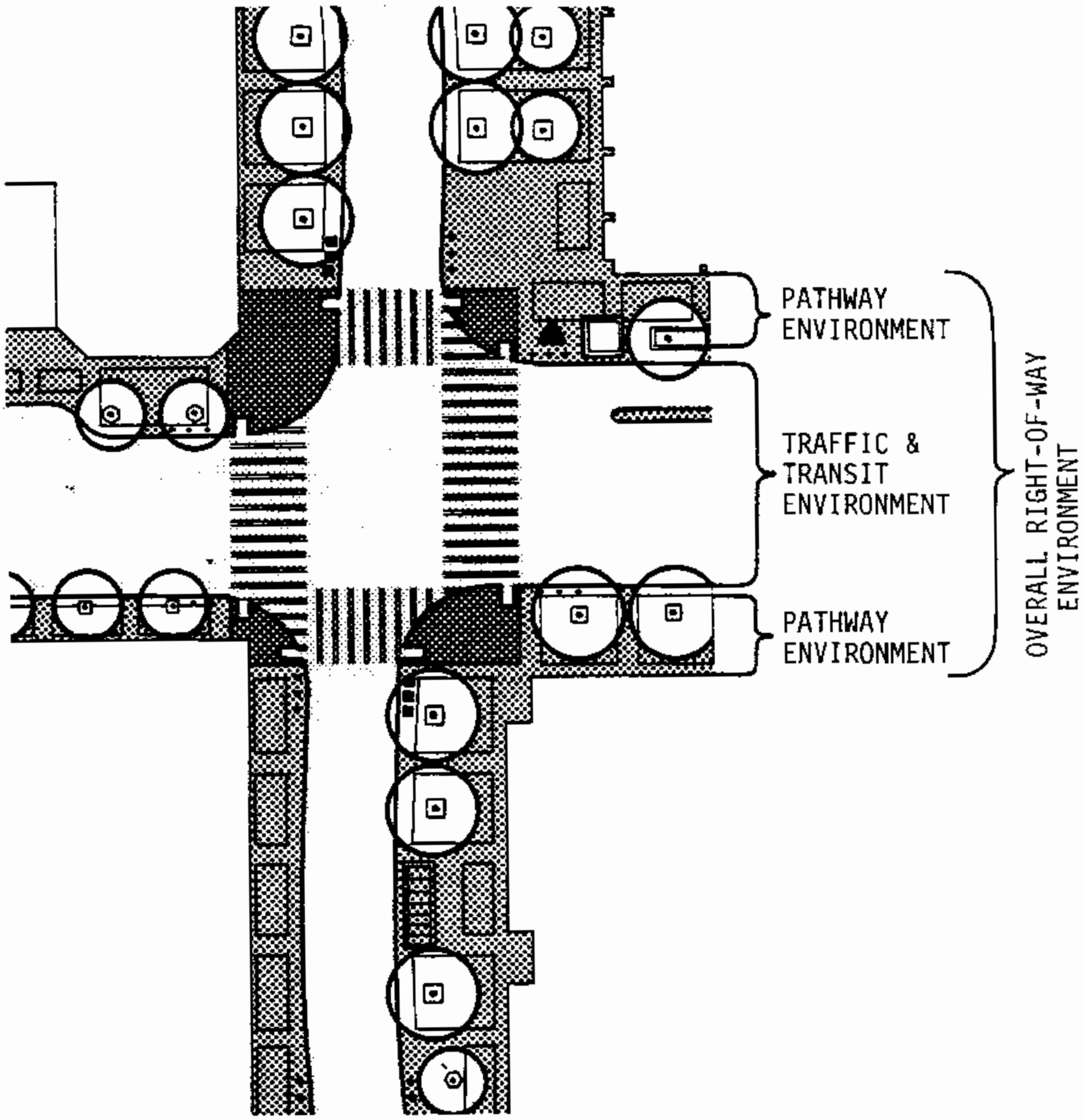


FIGURE 1-2

TYPICAL PEDESTRIAN SYSTEM INTERFACE ELEMENTS

1.2 Definitions and Notation Conventions for Pedestrian Networks

In developing pedestrian networks, the principal network elements, or components to be considered are:

(1) Centroids -- also referred to as activity centers, generators or attractors. Centroids represent various land uses which serve as the primary origins and destinations of pedestrian trips, or act as focal points of pedestrian activity. Typical examples of centroids are:

- mode transfer points (e.g., bus stops, train and subway stations)
- parking facilities
- residential concentrations
- offices
- retail stores and shops
- restaurants, theatres, etc.

(2) Pathways -- also referred to as pedways or walkways. Pathways serve to accommodate pedestrian movement between centroids. The typical pathway example is the ordinary sidewalk. Pathways consist of two secondary elements --

Nodes -- which are points where network pathways intersect, and where centroids connect to the network pathways; and

Links -- which are the pathway elements between two nodes.

A related collection of pedestrian centroids and pathways (nodes and links) form a pedestrian network.

Centroids should be represented as numbered open circles, where the number contained within the circle (the centroid label) uniquely identifies that centroid. Similarly, nodes should be represented as numbered solid circles, and labeled to uniquely identify each node. The labeling convention employed can be chosen by the user for convenience and familiarity. A labeling convention used in the procedures for centroids is presented in Appendix B.

In order to provide for the consistent reference to network elements, the following notation has been used:

C(I) = Centroid I, where I is the label assigned to the centroid;
N(X) = Node X, where X is the label assigned to the node.

Hence, C(101) will be used to represent the centroid labeled 101, and N(3) will represent Node 3.

Pathways will be described by the following notation using W to represetn "walkway" -

$W(I,J;\ X_1,X_2,\ \ldots)$

where I is the label of the pathway origin centroid, J is its destination, and the X_1, X_2, ... represent the nodes connecting pathway links. A specific link will be given as -

$$L(X_1, X_2)$$

where X_1 and X_2 are nodes connected by the pathway link.

For example, consider Figure 1-3. A pathway from C(102) to C(104) would be written as -

W (102, 104; 4, 5, 6, 7, 8, 9).

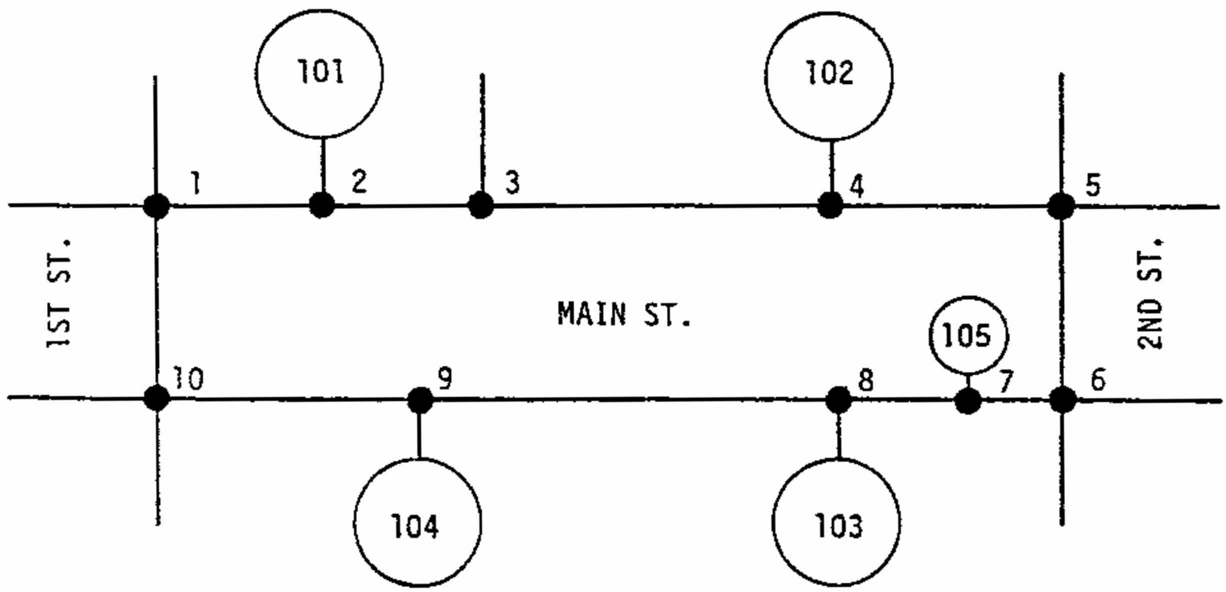


FIGURE 1-3

TYPICAL PEDESTRIAN NETWORK REPRESENTATION

An abbreviated notation can usually be used, provided no ambiguity exists, so that the above example pathway could have been written as

W(102, 104; 6) or as W(102, 104; 5).

Note that the same pathway between the two centroids is described in each case. An alternative pathway connecting the same two centroids is given by -

W(102, 104; 10).

For reasons that relate to the difference in the walking experience as a function of the directon being traversed along the pathway, the pathway from C(I) to C(J) may be considered as distinct from the pathway from C(J) to C(I). That is,

W(102, 104; 5) ≠ W(104, 102; 5)

For example, a trip from C(I) might require a grade change up to C(J), where the trip from C(J) to C(I) would require a downward grade change; and the two trips would represent different walking experiences.

1.3 Utilization and Pathway Choice

The extent to which a pedestrian system will be utilized by the pedestrians for whom it was intended is a central consideration in the planning and design process. Basically, given the individual's desire to go from point A to point B, the question is: What is his propensity to make the trip as a pedestrian, as opposed to making it via another mode, or not make it at all? Experience has shown that this pedestrian trip making propensity is attenuated as a function of the effort real as received required to make the trip on foot. The effort required will be proportional to the impedance characteristics of the pathway connecting the two points, where an impedance is any characteristic of the pathway that affects the time, distance and/or energy - both real and perceived - needed to make the pedestrian trip. Hence, a relationship between pedestrian trip propensity and impedance similar to that shown in Figure 1-4 exists.

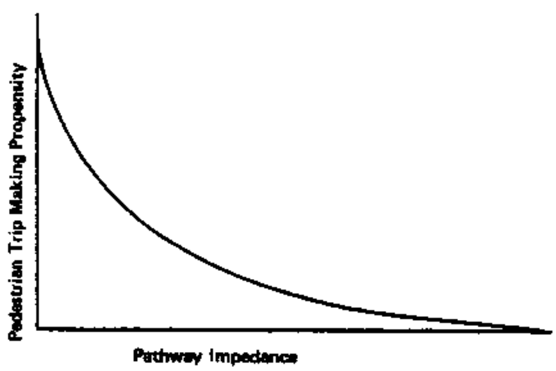


FIGURE 1-4

PATHWAY IMPEDANCE
RELATIONSHIP BETWEEN TRIPMAKING AND PATHWAY IMPEDANCE

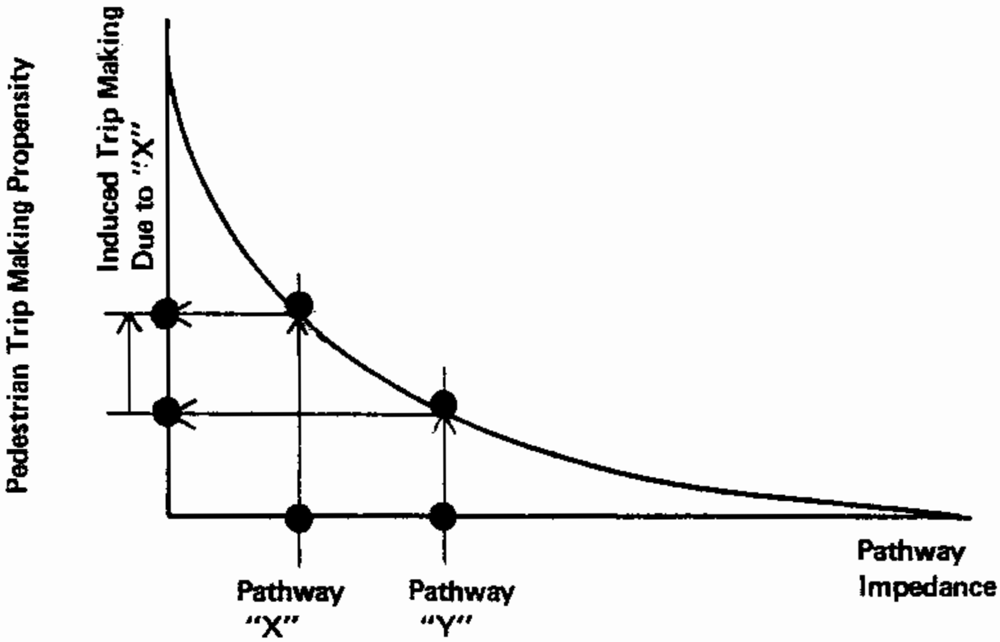


FIGURE 1-5

TRIPMAKING ON PATHWAYS WITH DIFFERENT IMPEDANCES

A conceptual model of pedestrian utilization is shown in Figure 1-5. In general, the pedestrian synthesizes two types of information regarding a desired trip:

- Pathway attributes, or characteristics of the walking environment likely to be encountered during the proposed trip, and

- Individual attitudes and perceptions regarding the pedestrian experience, depending on the purpose or objective of the proposed trip.

From this synthesis, a notion of impedance is developed which is translated through pedestrian behavior into an effect on network utilization and pathway choice.

When impedance is small, there is a great propensity to make pedestrian trips; but as impedance increases, this propensity reduces to the point where a pedestrian trip is no longer feasible.

Therefore, the amount of impedance found, in general, within a pedestrian system will have an impact on pedestrian trip-making propensity, and the extent to which the system is utilized.

Another aspect of the utilization notion deals with pathway choice. That is, how does the existence of alternative pathways between two given points affect pedestrian behavior. In Figure 1-5, two pathways with different impedances are indicated. Since pathway "X" s characterized by less impedance than pathway "Y", it should be utilized by a greater percentage of all pedestrians making the trip. Furthermore, it should induce some pedestrian trips to be made that would not have been if "Y" were the only route.

Experience has shown that pathway "X" would probably be utilized by nearly all pedestrians, especially for those trips where a "shortest route" syndrone would apply. Hence, the reduction of pathway impedance, in the case of alternative pathways, would greatly affect pathway choice, and could also induce increased utilization of the overall system.

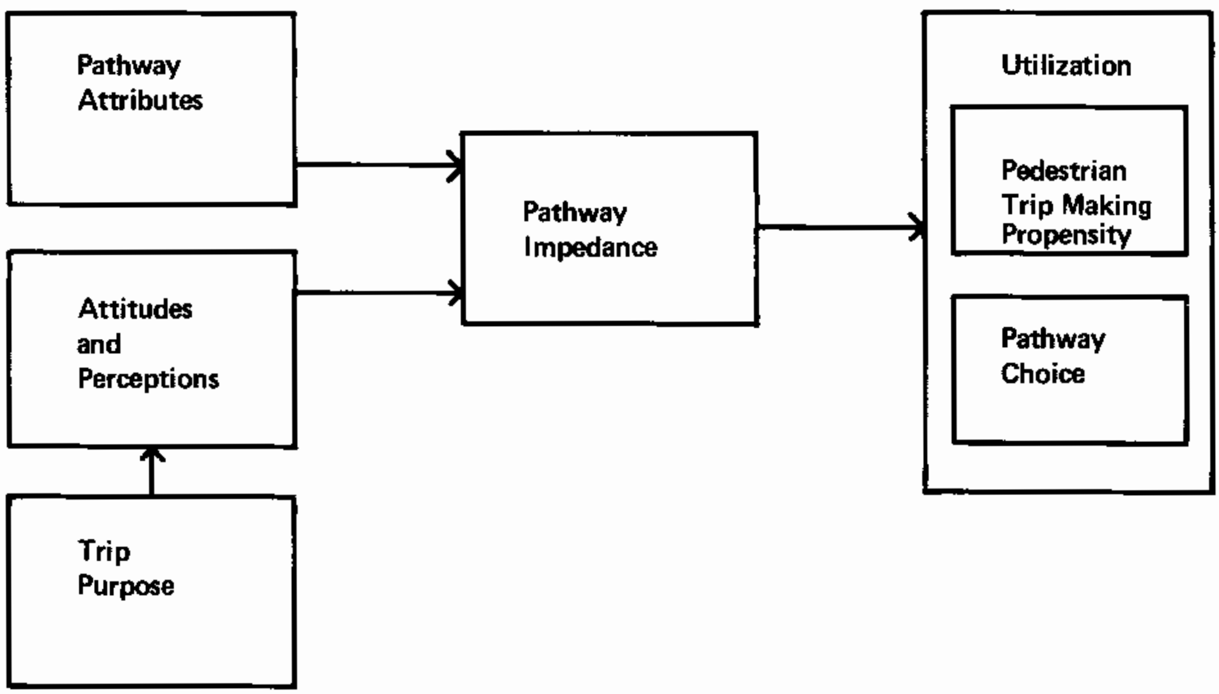


FIGURE 1-6

CONCEPTUAL MODEL OF PEDESTRIAN UTILIZATION

Elements shown on Figure 1-6 are described in more detail in subsequent sections, as follows:

Pathway Impedances	Section 1.4
Pathway Attributes	Section 1.5
Pedestrian Attitudes and Perceptions	Section 1.6
Trip Purpose	Section 1.7

1.4 Pathway Impedances

Pathway impedances are those elements of the pedestrian experience that influence the real and/or perceived separation between two points. In general, this notion of impedance, or separation, is a function of the pedestrian trip-making environment - that is, the attributes of the pathway between the two points, and the attitudes and perceptions of the individual(s) making the trip, in terms of how they relate to the pathway. The latter will usually vary as a function of trip purpose; a shopper is apt to react to a given pathway in a manner that is substantially different from that of a commuting pedestrian.

Impedances can be classified into three generic groups, as follows:

Impedances Affecting Movement

- Irregular pathway configuration - indirect routing, turning movements, hills, inadequate access to pathway
- Vehicular/pedestrian conflicts - delays due to vehicular traffic
- Pedestrian/pedestrian conflicts - crowding, queues, crossing interference, lack of pathway capacity
- Vertical change elements - stairs, ramps, inoperable escalators, delays at elevators
- Physical barriers - obstructions such as improperly placed street furniture and fixtures, pathway discontinuities
- Maintenance - inadequate maintenance or enforcement of municipal ordinances

Impedances Affecting Physical Comfort

- Environmental - inclement weather, noise, air pollution, wind
- Vehicular/pedestrian conflicts - risk to safety due to vehicular traffic
- Amenity - inadequate provision of benches, shade, water fountains

Impedances Affecting Psychological Comfort

- Unattractive elements - "deadwalls", inactive areas, abandoned buildings

- Disorientation - lack of directional information, signing, visual cues
- Poor security - real or perceived crime, undesirable elements (gangs, skid rows)

For any given pathway, the impedances affecting movement generally give rise to a physical separation between two points that can be expressed directly in physical units such as time, distance or energy. Hence, these impedances represent an invariant physical condition of separation which will be termed nominal separation. Physical comfort and psychological comfort impedances, on the other hand, represent factors that add to the perceived separation between two points. That is, an unfavorable condition, such as heavy vehicular traffic, may represent a perceived risk to the pedestrian; this risk represents an obstacle in much the same way that a stair, for example, represents an obstacle. Hence, the perceived risk would contribute to the real, or nominal, separation. The combination of nominal separation with other perceptual factors results in an effective separation of two points. Effective separation is analogous to the generic term impedance as it was used in Section 1.2.5.

A basic objective in pedestrian planning and design is to reduce effective separation, or impedance, by controlling pathway attributes. A description of these attributes is given in the next section.

1.5 Pathway Attributes

Pathway attributes are those characteristics of pedestrian system elements that encourage, or discourage, pedestrian activity and use of the links. These attributes are closely associated with the notion of pathway impedance that is discussed in the next section. As shown in Table 1-1, the attributes can basically be classified into three different groups, each of which is discussed below.

Movement Attributes
- Directness
- Continuity
- Capacity

Physical Comfort Attributes
- Environmental Protection
- Safety
- Amenity

Psychological Comfort Attributes
- Attractiveness
- Coherence
- Security

TABLE 1-1

IMPORTANT PATHWAY ATTRIBUTES

(1) Movement Attributes

This group contains those characteristics of a given pathway that relate to the extent to which pedestrian movement on the link is facilitated. Included in this group are:

Directness - A measure of the time, distance or energy required to negotiate a pathway between two centroids. Directness, as a measure, can be used to describe the extent to which a pathway deviates from a most direct alternative path.

The most direct path, measured in terms of distance, would lie along a line-of-sight vector connecting the two points, hence, using distance, a measure of pathway directness could be -

D(ABS) = absolute measure of directness (in terms of distance),

$$= \frac{\text{line-of-sight distance}}{\text{distance using pathway}}$$

Note that is the distance along the pathway equalled the line-of-sight distance, the D would equal 1, the maximum value for D.

In practice, it is usually more convenient to measure directness on one pathway relative to that of another alternative path. Then D(REL) = relative measure of directness of path (A) to path (B)

$$= \frac{\text{directness of path (A)}}{\text{directness of path (B)}}$$

where the directness measures for both paths are expressed in consistent terms of time, distance or energy.

Continuity - An attribute that expressed the extent to which a given pathway between two points is interrupted. These interruptions could consist of physical barriers, vehicular conflicts, necessity for vertical change, turning movement, queuing delays, need for directional decision and similar elements.

Continuity is often related to the concept of directness. A pathway may provide a line-of-sight connection between two points, thereby resulting in the maximum directness when measured in terms of distance. However, numerous discontinuities such as vehicular conflicts could cause delays that would degrade the path's directness if time were the measure.

Capacity - A measure of the extent to which a given pathway provides space required for pedestrian movement. Although capacity is often used to described the maximum volume of pedestrians that a pathway can accommodate, it is more accurately expressed as the volume of pedestrians that the pathway can accommodate given a specified quality of movement. This quality of movement is expressed in terms of the level of pedestrian crowding or congestion have been incorporated into a set of "level of service" standards which define a series of desired area modules for each pedestrian. To design to a specified level of service, the standard area module, together with a measure of the pedestrian volume demand, are used to compute a required effective walkway width (EWW). The maximum volume of pedestrian that this EWW can accommodate without reducing the specified level of service (average pedestrian area module) is its capacity.

(2) Physical Comfort Attributes

This group of attributes accounts for those characteristics of the pathway that contribute to the pedestrian's physical well-being. Attributes included in this group are:

Environmental Protection - This refers to the extent to which the pedestrian is protected from adverse or extreme environmental conditions while on the pathway. Depending on local conditions, this element may apply to protection from inclemency, temperature extremes, noise or air pollution, or any combination of effects. Where severe conditions do exist, provision of environmental protection has been shown to have a substantial effect on pedestrian movement behavior.

Safety - This refers to the extent to which the pathway provides the pedestrian protection from the threat of conflict with moving vehicles. Pedestrian safety is universally accepted as one of the primary benefits of pedestrian/vehicular separation. However, it is important to note that the central core of most cities is not an area of substantially high risk - where risk is the probability of being involved in an accident. This is especially significant considering the potential for accident reflected in the amount of exposure to moving vehicles that a pedestrian encounters in the urban core. Rather the greatest risk exists in surrounding areas immediately adjacent to an urban core. Of course, these observations are based on composite data, and cannot reflect conditions at specific sites. Safety is an important consideration, however, due to the way in which risk is perceived by pedestrians, even if the threat is not real. The notion of pedestrian perception and its importance to the design of systems is discussed in Section 1.6.

Amenity - Refers to the provision of benches, protected and shaded resting places, water fountains, rest rooms and other elements of physical comfort associated with the walkway.

(3) Psychological Comfort Attributes

The final group of attributes covers those pathway characteristics that contribute to the psychological well-being of a pedestrian using the link. Attributes included in this group are:

Attractiveness - Includes the concepts of visual interest and human activity. Visual or aesthetic interest refers to the uniqueness, drama, charm or contrast, as expressed in the form, color, landscaping, surface treatment, and similar aspects of the pathway. Activity refers to events occurring on, or adjacent to, the pathway which contribute to an ambience of attractiveness and excitement; this could include special events such as art shows, ordinary activity such as retailing, and can even extend to the existence of crowds.

Coherence - This relates to spatial and directional information that provide the pedestrian with orientation as he moves along the pathway. To facilitate movement, the key components of a coherent system are:

- Information - at the point of origin to provide orientation within the pathway system;
- Direction - to define the appropriate pathway which should be selected to reach another point in the system;
- Assurance - during the trip, to reinforce the confidence that the selected path is still being followed; and
- Confirmation - that the desired destination has, in fact, been reached.

Security - Defined as protection from the threat, and reality, of crime, such as mugging, robbery and similar criminal activity along the pathway. Security is enhanced by providing adequate lighting, sight lines, surveillance and policing. High levels of activity usually reduce the threat of criminal activity.

1.6 Pedestrian Attitudes and Perceptions

Pedestrian behavior is greatly influenced by individual attitudes and perceptions. Obviously, trip-making will be affected by physical aspects of the pedestrian environments; many dysfunctions, such as pathway discontinuities, excessive distance, or pedestrian/vehicular conflict, represent real impedances to walking. However, another set of factors that influence pedestrian behavior are those that modify this real walking experience through an individual's attitudes and perceptions.

Research has shown, for example, that pedestrians who purposely chose a given route over an alternative because it was thought to be shorter, often, in fact, had not chosen the shortest path. Something about the character of the pathway alternatives had modified their perception of distance. Studies indicate that perceived distance can be substantially affected by such pathway and environmental factors as attractiveness, physical comfort, familiarity, and similar elements. An understanding of these notions is essential to the successful development of pedestrian systems, and unfortunately they have been given inadequate attention too often in the past.

Behavior, as translated through perception, is a function of trip purpose (see Section 1.7.1 for a typology of pedestrian trip purpose). A simple representation of the way in which the perception of pathway attributes changes as a function of several elementary trip purposes is shown in Table 1-2.

In the planning and design of systems, it will often be necessary to consider trade-offs among perceptual variables. For example, a pedestrian bridge over a street with a very high risk of pedestrian/vehicular conflict may go unutilized because - in a perceptual sense - pedestrians assess the safety risk as being less important than the inconvenience of negotiating the change in grade required to use the bridge. Similarly, a pedestrian tunnel that provides a safe, direct route may go unused because tunnels often invoke a perceived threat to the individual's security which outweighs the inconvenience and risk of using an alternative pathway.

Pathway Attribute	Trip Purpose		
	Commute	Shopping	Recreational
Directness	high	medium	low
Continuity	high	medium	low
Capacity	high	medium	low
Protection (Envir)	medium	high	low
Safety	high	medium	high
Amenity	low	medium	high
Attractiveness	low	medium	high
Coherence	medium	medium	medium
Security	medium	high	medium

TABLE 1-2

RELATIVE PERCEIVED IMPORTANCE OF PATHWAY ATTRIBUTES AS A FUNCTION OF TRIP PURPOSE

1.7 Pedestrian Movement Characteristics

In this section, several characteristics of pedestrian group behavior that are of particular interest in the planning and design of systems are discuss namely:

- Trip Purpose
- Volumes and Capacity
- Temporal Patterns
- Trip Length

1.7.1 Trip Purpose

Trip purpose is defined as the motive, or reason, for making a given pedestrian trip from a point of origin to a point of destination. Usually this motive can be deduced from the nature of the destination node land use; for example, a trip to a retail store is usually construed to be a trip made for the purpose of shopping.

Table 1-3 provides a framework for classifying pedestrian trips by purpose.

GENERAL CLASSIFICATION	TRIPS CONSIDERED WITHIN PPP MANUAL
I. TERMINAL TRIPS	X
II. RESIDENTIAL TRIPS	X
III. FUNCTIONAL TRIPS	
A. BUSINESS	
1. Work	X
2. Personal	X
B. SHOPPING	
1. Primary	X
2. Employee	X
3. Incidental	X
4. Lunch	X
C. MISCELLANEOUS	
1. Deliveries	
2. Maintenance	
3. Others	
IV. RECREATIONAL TRIPS	
A. EXERCISE	
B. CULTURAL	
C. SOCIAL	
D. SIGHTSEEING	

TABLE 1-3

TRIP PURPOSES

Four basic types of trips are defined:

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

II. Residential Trips - Trips made having the trip-maker's home as either their origin or destination.

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

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

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

IIa. Business Trips - Non-terminal trips made in conjunction with work or the procurement of professional services that do not involve either an actual or potential purchase, such as trips between offices and banks, and trips to doctors or lawyers;

IIb. Shopping Trips - Non-terminal trips made for the purpose purchasing a product or personal service (dry-cleaners, barber), including eating and drinking;

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

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

II.b.1. Primary: Shopping trips made by persons whose sole purpose is making a purchase;

II.b.2. Employee: Shopping trips made by employees who shop before or after work, or on their lunch hour;

II.b.3. Incidental: Shopping trips made by persons who have another primary trip purpose and shop incidentally;

II.b.4. Lunch: A special category of shopping trips made mostly by office workers and similar employees to restaurants and cafeterias during their lunch hour.

Within the context of the trip purpose framework shown in Table 1-3 an almost unlimited combination of trips is possible; for example, a business meeting may be combined with lunch, or a newspaper may be purchased on the way to the subway. Also, a more explicit temporal component could be added; for example, to differential "AM" terminal trips from "PM" terminal trips.

Within the general framework provided by Table 1-3, trip purpose can be further subdivided, or consolidated, to suit specific situations.

In the Procedures Manual, Task 3, trips are characterized by their origin/destination pairing rather than by reference to the classification scheme presented in Table 1-3.

1.7.2 Volumes and Capacity

Pedestrian volume is defined as the number of pedestrians passing a given point, or section of pathway, during a specified period of time. Volume can be expressed as a function of pedestrian speed of movement, density and walkway width. For example, a one-minute measure of volume could be

$$V \frac{\text{peds}}{\text{min}} = \text{volumes in pedestrians per minute}$$

$$= S \times D \times W$$

Where S = pedestrian walking speed in feet per minute,
D = density in pedestrians per square foot, and
W = walkway width.

The measure of pedestrian volume can take many forms. Typical units of measurement are:

- Average daily volume (ADT) - The average of pedestrians recorded during a typical daily period, usually a 12-hour (7:00 a.m. to 7:00 p.m.) weekday;
- Average hourly volume - The average daily volume divided by twelve;
- Peak hourly volume - The average maximum one-hour volume recorded during a typical daily period;

- Peak 15-minute volume - The average maximum volume recorded during a 15-minute period on a typical day; this usually occurs within the peak hour;
- Peak minute volume - The average maximum volume recorded during a one minute period on a typical day; this usually occurs during the peak 15-minute period; and
- Other measures employing a temporal constraint such as the peak noon hour volume or the average a.m. peak hour.

Examination of pedestrian volumes is generally more comparable if the variation due to walkway width is factored out. This gives rise to the term pedestrian flow, where

F = pedestrian flow in pedestrian per unit of time per foot of walkway width

$$= S \times D = \text{speed} \times \text{density}$$

Flow is usually measured in terms of minutes, that is, in pedestrians per foot of walkway width per minute (abbreviated to PFM). When density is low and speed is unrestricted, flow will be minimal due to the low density. As density increases, flow will increase to a maximum value. Beyond this maximum value, further increases in density so severely restrict walking speed that the flow begins to decrease. The maximum flow is often referred to as the "capacity" of the walkway. (See also 1.2.7.1 under "Capacity".)

Design of walkways to carry maximum capacity may not be desirable due to severe densities that may result. Therefore, an approach has been developed based on the reciprocal of density the pedestrian space, or area module. The module is expressed as

M = pedestrian area module in square feet per pedestrian

$$= \frac{1}{D}, \text{ where}$$

D is the density in pedestrians per square foot. Capacity can then be expressed as a function of walking speed, S, and M, the area module; but S is a function of M so that -

$$F = \frac{S}{M} = f(M).$$

The relationship between F and M is somewhat complex, and to simplify the examination of capacity requirements, M is usually expressed in terms of a range of values known as a <u>level of service standard</u>. These different spatial standards will then yield different walkway capacities, depending on conditions, from free movement to impeded movement (crowding). Example levels of service for two directional flows yield the values shown in Table 1-4.

Level of Service Standard	Area Module (Square Feet Per Ped)	Walkway Flow (PFM)
A	35 or more	5 to 7
B	25 to 35	7 to 10
C	15 to 25	10 to 15
D	10 to 25	15 to 20
E	5 to 10	20 to 25
F	less than 5	severely limited

TABLE 1-4

LEVEL OF SERVICE STANDARD CHARACTERISTICS

Finally, the level of service standard can be chosen to accommodate average, peak or any other appropriate volume or flow.

1.7.3 Temporal Patterns

During a typical 12-hour daily period, the volume of pedestrian movement within an urban network exhibits wide fluctuation. The movement generally follows a temporal pattern consisting of six phases as described below and illustrated in Figure 1-7.

(1) 7:00 to 9:00 a.m. - The morning period of increased activity, dominated by employees moving from their point of mode transfer to their place of employment, with the peak generally occurring between 8:00 and 9:00 a.m.;

(2) 9:00 to 11:00 a.m. - The morning period of reduced activity, consisting of diverse trip purposes including business trips, early shopping trips and some commuters;

(3) 11:00 a.m. to 2:00 p.m. - The noon period of intense activity, consisting of lunch trips, primary and employee shopping trips and personal business trips, with the peak generally occurring between noon and 1:00 p.m.;

(4) 2:00 to 4:00 p.m. - The afternoon period of reduced activity, characterized by a diversity of trip purposes augmented by an increasing level of shopping activity;

(5) 4:00 to 7:00 p.m. - The early evening period of increased activity, dominated by employees and shoppers moving from offices and stores, respectively, to points of mode transfer, with the peak generally occurring between 5:00 and 6:00 p.m.;

(6) 7:00 p.m. to 7:00 a.m. - The overnight period of reduced activity depending on store closing hours, entertainment activities and similar factors.

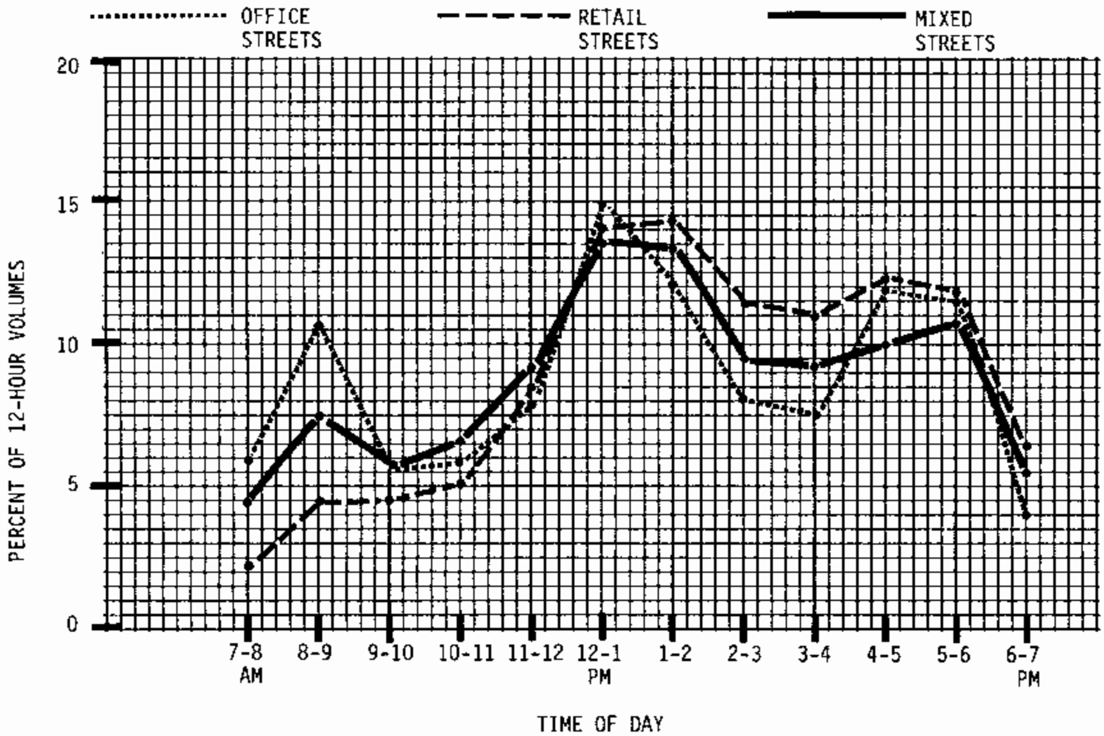


FIGURE 1-7

TYPICAL TEMPORAL PATTERN OF PEDESTRIAN VOLUMES
MIXED RETAIL AND OFFICE STREETS
(AVERAGE OF THREE SITES)

The temporal pattern of movement will vary as a function of trip purpose. For example, pedestrian trips associated with commutation to and from work generally peak during periods (1) and (5). Shopping by downtown employees usually peaks during period (3). The overall temporal pattern will vary depending on the trip purpose mix, but in general will follow the typical pattern illustrated in Figure 1-7.

The degree to which pedestrian movement is concentrated in the three daily peak periods is of particular significance to the planning and design of pedestrian systems. These peaks represent the maximum aggregations of movement. Accommodation of this aggreated movement will give rise to maximum utilization of system pathways, and to the extent that the system is used, will result in the highest levels of derived benefit. Hence, most attention to movement as it affects planning and design will be focused on the peak periods. It is recognized, of course, that different walkway segments may experience maximum utilization during different peak periods.

Figure 1-7 illustrates hourly peak movement patterns. These hourly peaks actually represent an average of more concentrated peaking conditions that occur for short duration during any given hour. For example, since movement during peak periods is not uniform, a given 15-minute period within the peak hour will probably experience a volume far in excess of the hourly average. This is illustrated in Figure 1-8.

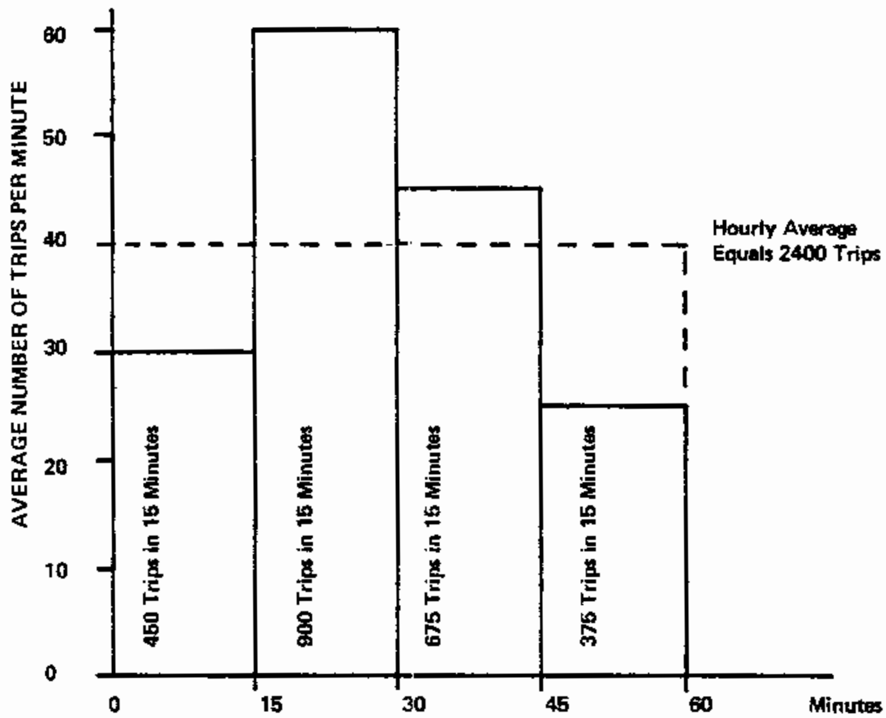


FIGURE 1-8

TYPICAL 15 MINUTE PEAKS WITHIN AN AVERAGE PEAK HOUR OF 2400 TRIPS

In general, planning to accommodate movement during the daily 15-minute peaks is sufficient. However, within each 15-minute peak there will probably exist "spikes" such that large volumes occur during very short periods. For example, there usually exist one-minute peaks within the peak 15-minute period in a manner similar to that illustrated in Figure 1-8 for 15-minute peaks with an hourly peak. These one-minute "spikes" are often important in the examination of capacity requirements.

In order to simplify analysis, it is usually sufficient to express the peak 15-minute or peak one-minute volumes as a multiple of the peak hourly volume, or similarly, to express the one-minute peak as a multiple of the 15-minute peak. For example, experience has shown that the peak one-minute volume within a 15-minute peak will usually be about one-third greater than the average minute (during the 15-minute peak) hence.

$$\text{Peak one Minute Volume} = 1.33 \; \frac{\text{15 minute peak volume}}{15}$$

Other temporal variations of interest are weekly and seasonal cycles, and those that affect directionality of movement. In particular, directional flow changes during the daily period are of interest, due to their potential impact on location of mode transfer points such as bus stops or subway portals, or on operation of mechanical systems such as ascalators. While weekly variation is usually of minor interest for systems in urban cores, where wide fluctuations occur this would have to be taken into account. In the cores of smaller cities, for example, shopping trips might be considerably higher on Saturdays than on weekdays. Seasonal variation is important, especially as it influences the need for environmental protection.

1.8 Trip Length and Inter-nodal Separation

It has been determined that as travel distance or trip length between origin and destination increases, the propensity or willingness to make walking trips decreases to the point where alternative means of transportation will be used or, in fact, the trip will not be made at all. The relationship between distance and trip-making, based on a composite of numerous American cities, is illustrated below:

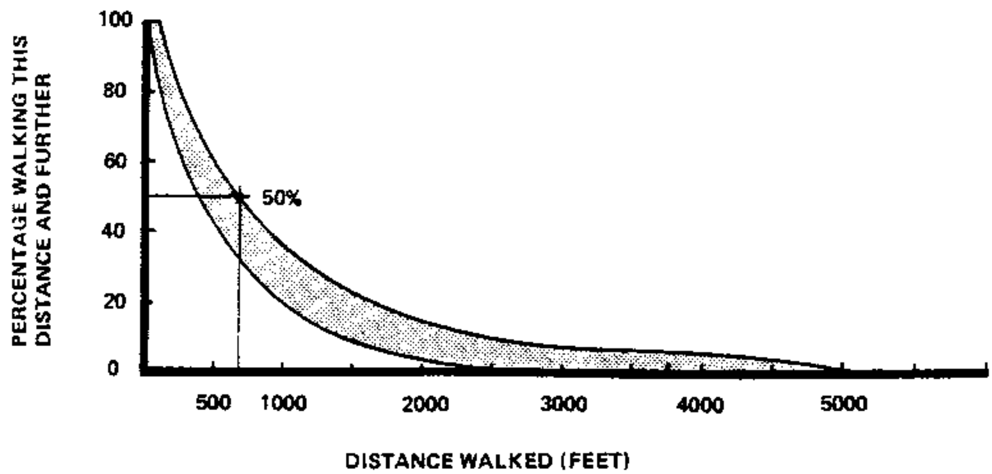


Figure 1-9

Range Of Walking Distances

Since the curves illustrated in Figure 1-9 represent the way in which trip propensity is attenuated with distance, they are often referred to as "pedestrian trip attenuation curves". Similar relationships exist using trip time as the independent variable substituted for trip length.

In Figure 1-9 it can be noted that there is a substantial variation in trip-making propensity for any given distance. Some of this variation can be explained by the disposition of site-specific land uses in the cities examined. That is, a very dense and diverse urban core should give rise to shorter trips than one that is less dense; as land uses such as shopping, offices or bus stops become more separated - but still within "reasonable" walking distance - the trip will become relatively longer. Another significant factor is that the distance walked is related to trip purpose. Research has shown that someone walking from home to work for example, will be prepared to walk considerably further than one walking from a parking garage to work. Figure 1-10 based on such research, illustrates this phenomenon. The characteristic mix of trip purposes within the cities then, further accounts for the variation in Figure 1-10. The availability of alternative transport modes is yet another influencing factor.

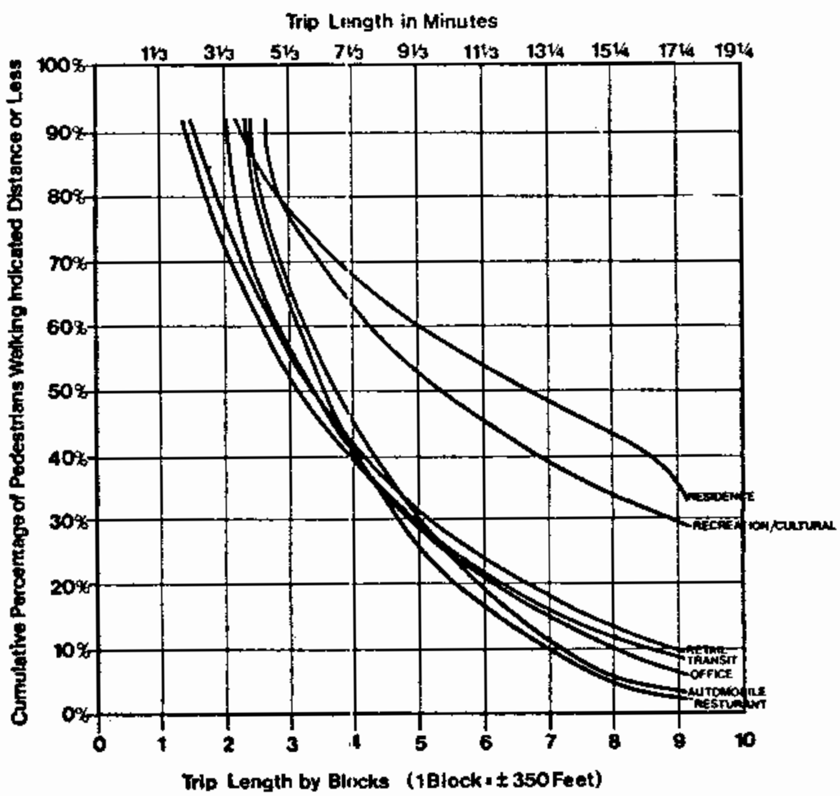


FIGURE 1-10

CUMULATIVE DISTRIBUTION OF TRIP LENGTH BY PURPOSE

The different quality furthermore of the walking environment between cities will also affect the trip attenuation relationship. This is because the pedestrian's perception of time and/or distance will be altered by the environment. Where walking is a pleasant experience, trips are apt to be longer because time or distance are perceived to be less than they actually are. In a given trip purpose, the extent to which the environment, and in particular, specific attributes of the pathway, are perceived as impedances has the greatest influence on trip attenuation. This is the basic concept that was introduced in Section 1-4 above, and illustrated in Table 1-1 and 1-2 in that section.

In the procedures, the term "separation" is used to replace "impedance". In reality the terms are synonymous within the context of pedestrian movement. The separation of two points, however, more adequately describes the measure.

In addition to spatial separation (walking distance) and temporal separation (trip time) considerations, typical pathway elements that contribute to the real or perceived pedestrian separation of a centroid pair are:

Vertical Displacement

- stairs
- ramps
- escalators
- elevators

Horizontal Displacement

- turning movements
- directness
- impedances (barriers)

Delays

- crowding
- queues
- waits

Psychological and Physiological

- comfort
- security
- safety
- interest, etc.

The term effective separation will be used to describe the distance between two points as perceived by pedestrians as a function of time, distance or other influencing elements as cited above. Distance, time and energy (under average conditions) represent invariant measures of separation associated with a given pathway. These measures might then be used to establish a nominal separation that would be modified by behavioral or perceptual factors to obtain the effective separation. For example, 1000 feet of pathway, characterized by numerous points of interest, may be perceptually shorter than 1000 feet to a pedestrian on a recreational trip; but may still appear as 1000 feet to a commuter going from a bus stop to a place of employment.

In the procedures, nominal separation measures will be expressed in terms of time usually as minutes. Distance and energy will be converted to time using pedestrian movement on level, unimpeded pathways as the normative condition. Tests have shown that the average pedestrian walks at a rate of 265 feet per minute, and in doing so, expends 4.38 calories per minute. Hence, for converting distance and energy to time, the following equivalents will be used:

1 Minute = 265 feet = 4.38 calories

Departures from this normative condition will be necessary if the pedestrian group under consideration is composed of children, aged, the handicapped or similar elements.

Nominal separation can usually be determined in a straightforward way using methods provided in the procedures. Having determined this measure for a given pathway, existing data on the pedestrian perception of various pathway attributes is used to modify nominal separation to obtain a measure of effective separation. Depending on the way in which the pathway is perceived, the effective separation may be less than, equal to, or greater than the nominal separation. This is illustrated in Figure 1-11 for a case where the pathway attributes are perceived as favorable. If the net perception of the pathway had been unfavorable, the adjustment shown in the figure would be added to (rather than subtracted from) the nominal separation.

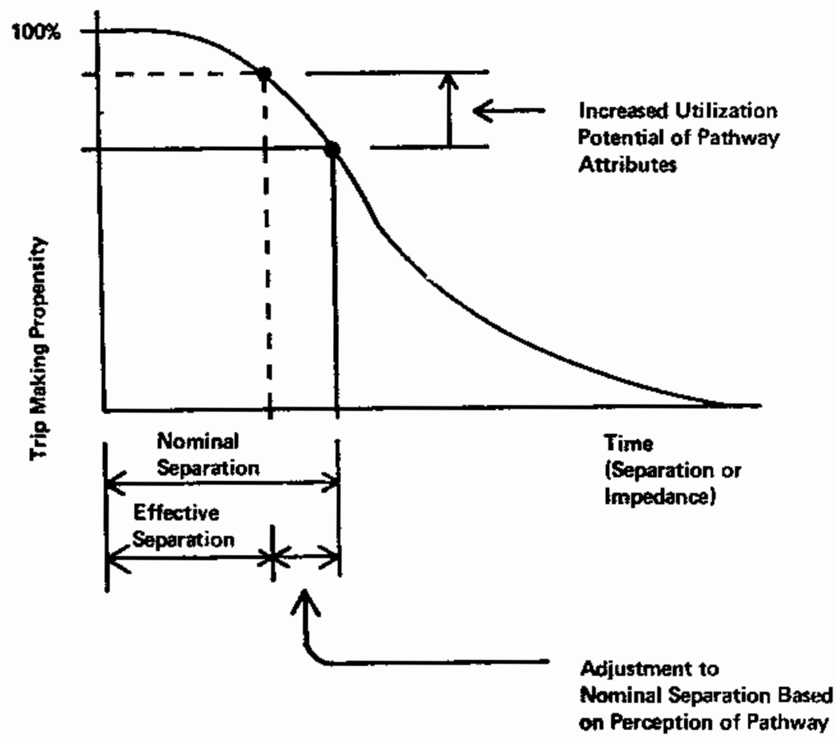


FIGURE 1-11

RELATIONSHIP BETWEEN NOMINAL AND
EFFECTIVE SEPARATION (FAVORABLE)

The magnitude of the adjustment will depend on perception of pathway attributes as a function of trip purpose. For example, pathway directness will usually be more important to a commuter than to a shopper. Hence, the adjustment to nominal separation based on pathway directness will be greater for commutation trips than for shopping trips.

1.9 Pedestrian Trip Exchange

The examination of the manner in which, and the extent to which, pedestrian trips are made, or exchanged, within a network is a fundamental importance in the planning and design of pedestrian systems. Methods for conducting this examination may range from volume counts on links, cordon counts, tracking studies, photometric techniques, and mathematical modeling. Most direct methods such as counts are adequate for examining existing movement within a stable land use configuration. However, if the objective is to forecast movement patterns based on some future land use or network configuration, extrapolation of data gathered using direct methods may be invalid. Rather, a means of simulating the future situation is required. In this section, key aspects of the pedestrian trip exchange behavior and analysis used in the procedures, will be presented.

Many of the elements discussed in prior sections such as nodal generation, pathway impedance and trip purpose are synthesized in the examination of trip exchange. For a given trip purpose, the amount of pedestrian movement distributed within a predefined pedestrian network depends on four elements:

- The land use types associated with origins and destinations (centroids) contained by the network;
- The number of trips produced by origin nodes (to all destination nodes);
- The number of trips attracted by destination nodes (from all origin node;
- The accessibility of destination nodes to origin nodes.

Land use will largely determine the types of pedestrian trips that will be produced and attracted. For example, a department store is usually associated with an entirely different subset of pedestrian trips than a post office building.

For a given land use, the number of trips produced and attracted by an activity node is usually dependent on the size of the centroid. Large stores will produce and attract more trips than small stores, and so on.

Accessibility, that is, how accessible a desired destination is to a pedestrian originating a trip at a given node, will depend on the effective separation of two points as described in Section 18. Accessibility is essentially the inverse of separation, such that

$$\text{Accessibility} = \frac{1}{\text{separation (or impedance)}}$$

Thus, if the separation is minimal, accessibility is large, indicating good accessibility; however, if the separation is great, accessibility is small, or poor.

The extent to which trips will be exchanged between two points will be proportional to the trip production potential of the original node and the trip attraction potential of the destination node, and will be inversely proportional to the separation of the two nodes. However, pairs of nodes cannot be examined in isolation. For example, a given destination is actually competing with similar destination nodes in the network for trips from a given origin. Obviously a large attractor close to an origin will "capture" more trips from that origin than a smaller attractor further away. However, the more complex situations are not so obvious; for example, a large attractor located at a substantial distance from an origin may, or may not, attract more trips than a smaller counterpart located more closely.

The gravity model approach, developed to evaulate vehicular traffic demand, provides a means to similarly examine the analogous movement of pedestrian. The gravity model employs an iterative process that balances the centroid attraction potentials and the attenuation of trips as a function of intercentroid separations to effectively distribute trips produced within the network. The assignment of trips to pathway links represents the way in which trips would be exchanged within the actual pedestrian system.

The model has the following form:

T(I,J) = number of trips exchanged from origin I to destination J

$$= \frac{P(I) \cdot A(J) \cdot F(I,J)}{\Sigma A(J) \cdot F(I,J)}$$

Where P(I) = trips produced by origin I

A(J) = trips attracted by destination J

F(I,J)= a measure of the trip propensity between I and J as a function of their separation.

At each iteration of the model, the T (I,J) are computed. However, due to the complex interaction of the A(J) and the F(I,J), the sum of all trips attracted may not equal the sum of all trips produced. Therefore, the attraction potentials, the A(J), are adjusted proportionately and the model computations repeated. The process eventually converges (usually after not more than five iterations) to the point where the A(J) are stable and total to the sum of the trips produced. At this point the process is terminated and the T(I,J) from the last iteration taken as representative of the trip exchange.

Trip exchange components, consisting of different trip purpose during different temporal periods (peaks), can be computed and aggreated to obtain a profile of daily to model pedestrian volumes. Since it would be impractical to attempt to model all components of daily movement, the aggregated profile would not include all trips. However, it would provide a profile on the relative magnitude of utilization for each network link. This information, together with other criteria, would form the basis for subsequent planning and design decisions.

1.10 Pedestrian System Impact Assessment

During the planning and design phases leading to the development of a pedestrian system evaulation tasks have been incorporated to meet the need for continuously evaulating the system being developed. These evaulative exercises can subsequently be examined to ensure that:

- Pre-stated policies, goals and/or objectives are being met;
- Planning and design trade-offs are being resolved in a satisfactory manner; and
- Planning and design decisions are correctly influencing pathway utilization potential.

In the strict sense, impacts can be thought of in terms of positive impacts - usually called benefits, and negative impacts - usually called costs. In this manual, however, a different interpretation will be used. The term cost will be used to refer to those elements of pecuniary impact associated with the construction, operation, and maintenance of the system. The term impact will be reserved for effects resulting from use of the system by pedestrians. Hence, system implementation gives rise to costs; system utilization gives rise to impacts.

Furthermore, system impacts will be distinguished as positive and negative. Positive impacts will usually be referred to as benefits, while negative impacts will be referred to as dysbenefits. Both positive and negative impacts, depending on their nature, may be quantified in terms of monetary, or pecuniary, units. In general, however, the quantification of impact in pecuniary terms will not be possible, and some other appropriate measures will have to be employed.

The precise nature of the impact assessment, and its relationship to other evaluation activities, will depend on the specific planning and design function to which it applies.

In the following sections, costs and other impacts are discussed in general terms; more specific and operational methods for cost and impact assessment, and for the conduct of evaluations suitable to various planning and design activities, are presented in the Procedures.

1.10.1 System Costs

One component of pedestrian system impact is the cost of its implementation, operation and maintenance. In this section, a framework for estimating system costs is presented, and appropriate definitions of key cost contributing elements are provided.

A generalized framework for principle relating predestrian system cost elements is shown in Figure 1-12. The framework consists of five major components, each of which builds on those before it, which lead to the determination of an estimated system cost. The cost framework is intended for estimating the costs associated with system sub-elements, or individual pedestrian facilities such as malls or skyways. Total system costs are then obtained by aggregating the sub-element costs. The five major components and appropriate cost elements are described in the following sections.

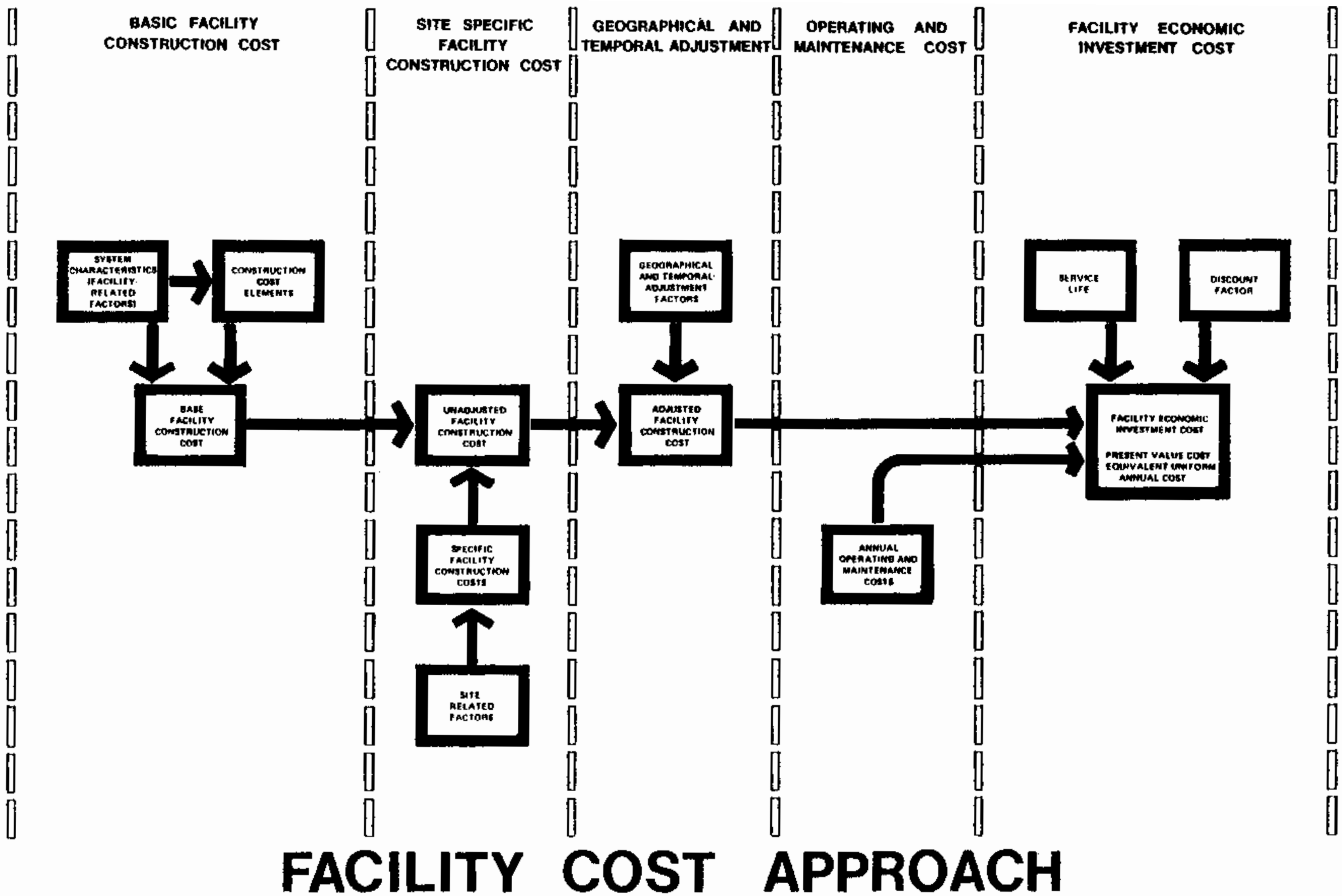


FIGURE 1-12

FACILITY COST APPROACH

(1) Base Facility Construction Cost

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

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

Both the unit cost and number of units are functions of several other factors as shown in Table 1-5, and described below:

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

TABLE 1-5

FACILITY-RELATED FACTORS THAT INFLUENCE BASE COST OF CONSTRUCTION

Facility Type

Base construction costs will obviously vary by the type of facility since it affects the unit cost of construction, and will also affect the dimensions used to determine the number of construction units. Specific facilities are discussed in Table 26.5. For the purpose of costing, the following generic facility types will be considered:

- Elevated skyways
- Street and highway underpasses (pedestrian tunnels)
- Vertical connections
- Street overpasses (pedestrian bridges)
- Full and partial at-grade malls

Dimensional Properties

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

Structural Properties

The structural properties of importance are:

- Length of clear span
- Method of facility support

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

Material and Construction Method

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

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

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

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

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

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

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

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

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

- Geographical or regional material supply characteristics

- Scarcity of supply resulting in long delivery times and possible delays

(2) Unadjusted Facility Construction Cost

In addition to the base cost described above, the construction cost of a facility will also depend on a great number of variables that are related to the specific site at which the facility is to be constructed. These variables were purposely eliminated in the previous section where the intent was to derive a base construction cost that was dependent upon factors associated with the facility itself, independent of the cost contingencies related to the facility site. In this section several of the site related factors that influence cost are discussed. No attempt has been made to delineate every site-specific cost contingency, but rather to detail those that tend to dominate or greatly influence total construction cost, or those, such as the cost of traffic delays during construction, which are often overlooked in economic analyses of proposed facilities. These site-specific factors give rise to specific facility construction costs which, in general, are added to the base cost to obtain an unadjusted facility construction cost (also called Facility Constructon Cost, or simply, construction cost). In the procedures, these specific costs are usually presented as cost ranges, rather than as point estimates, and the same interpretation of the data will be necessary. Factors that influence site specific costs, which are discussed below, are the following:

- Foundation conditions
- Utilities relocation
- Structural considerations
- 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 unusual construction requirements.

- Utilities Relocation

  Careful 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 in CBD areas. These utilities (water, gas, electric, telephone, etc.) may require relocation, replacement and upgrading depending upon both their location and their condition. In addition to physical relocation, existing utility lines may need to supported and protected from new construction; 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.

- Structural Considerations

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

  However, the consideration and selection of a structural system is also contingent upon several locational factors, such as the following:

  - Length to be spanned unsupported

  - Whether or not it is feasible to locate intermediate pier supports in medians within the road right-of-way

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

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

- <u>Traffic Delays During Construction</u>

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

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

a. Number of vehicles and traffic lanes affected by the construction per unit time

b. Average delay time per vehicle

c. Excess cost of vehicle operation due to speed reduction and idling per delayed vehicle

d. Value of vehicle time per unit time

e. Duration of construction

These factors listed above, the total time over which construction delays vehicles, can be controlled to reduce the impact of delay. The use of precast or prefabricated members, for example, results in longer allowable spans, reduced depth of structure and increased speed of erection.

Hence, while prefabrication is being done at a location off-site, on-site preparation can be accomplished concurrently since they are independent of each other. The net result is a considerable time savings in the overall construction process, as well as in the on-site erection.

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

Table 1-6 provides a simple relationship between material/construction type and time required to erect on-site. The actual extent of construction delays will depend on numerous other factors, but all things being equal, the impact of the construction technique employed will be shown.

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

TYPE OF CONSTRUCTION TECHNIQUE	TIME REQUIRED TO ERECT FACILITY ON-SITE			
	LESS TIME		MORE TIME	
	1	2	3	4
1. Prefabricated Steel Truss	X			
2. Standard Steel Construction		X		
3. Cast-in-Place, Concrete		X		
4. Cast-in-Place, Concrete,			X	
5. Precast Concrete	X			
6. Composite Steel and Concrete			X	
7. Concrete or Steel Arches, etc.				X

TABLE 1-6

COMPARATIVE TIME TO EREGT FACILITIES
ON-SITE VERSUS CONSTRUCTION TECHNIQUE

(3) Adjusted Facility Construction Cost

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

Geographical Differences

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

- Temporal Differences

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

  The unadjusted construction cost described in the previous sections represents average U.S. costs in 1976 dollars; these costs can be both temporarily and geographically adjusted by use of appropriate indices that are provided in an appendix to the procedures.

(4) Operation and Maintenance Costs

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

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

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

- Level of comfort provided
- Type of security required
- Availability of service

A percentage breakdown of O&M costs based on at-grade walkway systems in several major urban centers is given in Table 1-7.

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

TABLE 1-7

PERCENTAGE ALLOCATION OF O&M COSTS - CBD SYSTEMS

Source: RTKL Associates Inc. estimates

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

(5) The Facility Economic Investment Cost

In the preceding sections, the primary focus has been on the construction cost which can be expressed in current dollars. Although the cost of constructing large-scale pedestrian systems may involve capital investment over several years, very few problems are encountered in comparing the investment cost requirements of alternatives if only the costs of construction are considered. Unlike the costs of construction, however, the cost streams of expenditures for system operation and maintenance occur over the future years in which the facility is in service.

Money has a time-dependent value that makes an amount now on-hand worth more than the promise of an equivalent amount at some future time. Hence, in terms of their "present value", future expenditures are of lower value (cost less) than current expenditures.

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

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

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

Present Value Method

In the present value method, all costs both present and future are represented as a single sum which expresses the amount of capital required now (or at the start of the project) to finance facility construction and subsequent annual operating and maintenance expenses. This is accomplished by computing the present value of the O&M cost stream and adding it to the construction cost (assumed to be at its present value). The required computation is shown in Figure 1-13.

(PVC) = PRESENT VALUE OF FACILITY COSTS

= ADJUSTED FACILITY CONSTRUCTION COST + PRESENT VALUE OF O&M COSTS

= ADJUSTED FACILITY CONSTRUCTION COST + (PVF) X ANNUAL UNIFORM O&M COSTS

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 1-13

COMPUTATON OF THE PRESENT VALUE OF FACILITY COSTS

The present value computation in Figure 1-13 is expressed in its simplest form and assumes that the facility has zero salvage value at the end of its service life, and that annual O&M costs are uniform over the entire service life of the facility. The present value factors (PVF) have been tabulated for a wide range of i and N values, and are readily available.

The Equivalent Uniform Annual Cost Method

This method will yield results which are identical to those obtained using the present value method. In this case, the methods combine the cost of facility constructon 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 equivalent uniform annual cost method is often preferred by highway planners and the basic computation is shown in Figure 1-14.

(AC) = EQUIVALENT UNIFORM ANNUAL FACILITY COST

= EQUIVALENT UNIFORM ANNUAL COST OF FACILITY CONSTRUCTION + ANNUAL UNIFORM O&M COSTS

Where: (CRF) = CAPITAL RECOVERY FACTOR

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

FIGURE 1-14

COMPUTATION OF THE EQUIVALENT ANNUAL FACILITY COST

Sensitivity of Factors

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

The interest rate is probably the most critical factor since a change of several percent in the interest rate can change the results of the comparative analysis. Values between 5 and 12 percent are often used.* The impact is most significant when alternatives being compared have significantly different initial investment or annual O&M costs.

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

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

1.10.2 System Impacts

Pedestrian systems, depending on their degree of usage, impact in various ways on one or more affected groups. These impacts can generally be thought of as benefits, although the concept of potential negative impact, or dysbenefit, must be recognized. In most situations, the objective is to achieve and promote overall positive benefits; however, in some instances at the subsystem level, it may be advantageous to strive for negative benefit. An example of the latter would be the situation where an attempt is made to modify pedestrian behavior by discouraging use of a pathway (presumable to foster higher use on another alternative route).

*A useful guideline value is provided by the Federal Office of Management and Budget. The value is time dependent, consequently, a specific value has not been provided in this section.

The generic set of pedestrian system impacts, or benefits, can be classified into subgroups depending on the impacted group, as follows:

- Primary Impacts - Those impacts that accrue to the pedestrian - the primary system user; these impacts are usually referred to simply as pedestrian impacts;
- Secondary Impacts - Those impacts that accrue to groups - other than pedestrian/users - that interact directly with the pedestrian system; in particular, this includes motorists, abutting property occupants, and similar entities; and
- Higher Order Impacts - All remaining impacts attributable to the pedestrian system.

Illustrative examples of primary, secondary and higher order impacts are shown in Tables 1-8, 1-9, 1-10. In practice, a more definitive set of impacts may be used to conduct assessments.

- Pedestrian Safety (From Vehicular Conflict)
- Trip Times and Distances
- Accessibility (To Desired Activities)
- Environmental Protection (Including Noise and Air)
- Capacity (Crowding, Queueing)
- Security (From Threat of Crime)
- Ease of Walking (Uniform Surface, etc.)
- Continuity
- Provision for Special Groups (Handicapped, Aged, etc.)
- Coherence (Way-finding, Signing)
- Amenity and Comfort
- Interest
- Health (Excercise, Fatigue)
- Social Interaction

TABLE 1-8

ELEMENTS OF PRIMARY IMPACT
(PEDESTRIAN IMPACTS)
FOR PEDESTRIAN SYSTEMS

MOTOR VEHICLE

- Operating Costs
- Congestion (Air, Noise, etc.)
- Accessibility (To Desired Activities)
- Usage (Pedestrian/Vehicular Modal Choice)
- Motorist Frustration
- Accidents (Pedestrian/Vehicular Conflict)
- Diversion During Construction

ABUTTING ACTIVITIES

- Property Values
- Retail Sales
- Occupancy Rates
- Land Utilizaton Intensity
- Servicing (of Adjacent Activities)/Deliveries
- Employee Accessibility
- Clientele, Shopping Habits
- Attitudes (Workers, Shoppers, Merchants)
- Connectivity of Compatible Land Uses
- Greater Use of Sidewalk
- Displacement or Dislocation
- Renovation

TABLE 1-9

ELEMENTS OF SECONDARY IMPACT
(MOTOR VEHICLE AND ABUTTING PROPERTY)
FOR PEDESTRIAN SYSTEMS

FINANCIAL

- Net Increased Tax Revenue from Existing Sources
- Stabilitation of a Declining Tax Base
- Net Additions to the Tax Base
- Change in Cost of Providing Community Services
- Increased Employment form Increased Land Utilization

ENVIRONMENTAL

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

PERCEPTUAL

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

SOCIAL

- Less Littering
- Connectivity of Neighborhoods and Other Land Uses
- Less Crime and Vandalism
- Enchanced "Place-to-Be" Image
- Increased Hours of Activity
- More Public Events
- Attraction of Outside Conventions, Expositions
- Residential Dislocation
- Public participation in the Planning Process

TABLE 1-10

HIGHER ORDER BENEFITS
OF PEDESTRIAN SYSTEMS

The different levels of impact are related to the concept of utilization, discussed in Section 1-3. A conceptual model of this relationship is shown in Figure 1-15. Pathway attributes influeence both the real and perceived impacts experienced by pedestrians using the system. The extent to which these impacts are realized both reinforces the perception, and results in a decision to either use, or not use, the pathway. The degree of overall primary impact will depend on pathway utilization. Secondary and higher order impacts are then accrued as a function of preceding elements in the diagram.

The assessment of pedestrian impacts is still an evolving process. While substantial improvements in estimation methodologies have recently been made, a means for measuring each element, and for subsequently synthesizing individual elements into a single measure comparable to estimated system costs, is not available. Fortunately, however, it is often possible to estimate the relationship between primary (pedestrian) impact and utilization; also, given the level of utilization, reasonably good estimates of secondary impacts such as changes in vehicular delay costs, or in some cases, changes in retail sales activity. Therefore, if secondary impacts are substantial, it may be possible to compare costs and benefits to determine if system implementation is justified. Also, even where impacts cannot be expressed in pecuniary terms, an additive weighted score for impacts associated with competing alternative systems or with a "do-nothing" option will be sufficient to select the preferred alternative. Such a methodolgy is invoked in the procedures.

SUPPLEMENT 2
REPORT ON PERSON TRIP GENERATION FOR SELECTED LAND USES RELATIVE TO PEDESTRIAN PLANNING

TABLE OF CONTENTS

SECTION

I. INTRODUCTION

The purpose of this report is to document the analysis of person trip generation data and to present the results for use in pedestrian planning. The report is not intended as an operational guide, and is not suitable as a procedural manual. Rather, the results reported here should form the basis for development of a Pedestrian Generation Section for the Pedestrian Planning Manual.

An extensive data base consisting of generation measures was assembled. A listing for the primary sources is provided in Figure I-1. A total of 343 data points were examined. From this set, 286 points were selected for further analysis; the other data were excluded due to problems related to completeness, reliability, or compatibility. The data were distributed as follows:

Category	Number of Sites	Number of Data Points
A -- Offices	57	57
B -- Retailing	96	107
C -- Food-Related	23	58
D -- Parking	--	--
E -- Residential	39	64
	215	286

Parking was treated differently than the other categories using existing parking generation studies and analyses; appropriate data are tabulated in Section V. Several sites were characterized by more than one data point; for example, weekday and weekend trips counts were available for many Category C restaurants.

Each category is examined in detail in the sections that follow. The following notation is used throughout the remainder of this report:

N = Number of data points examined;

R(I) = Trip generation rate for Site I; usually expressed as person trips per hour per 1000 ;

$\overline{R}$ = Mean value of the R(I)
(1/N R(1)

S(R) = Standard deviation of the R(I);

V = Relative dispersion;

= S(R)/R;

1. Pushkarev and Zupan; Urban Space for Pedestrians

2. Creighton; Report on the Walking Trip Survey; Chicago Area Transportation Study

3. Ness, Morrall and Hutchinson; "Analysis of CBD Pedestrian Circulation Patterns; "Highway Research Record No. 283.

4. Levinson; Modeling Pedestrian Travel; March, 1971

5. Wright; "Relationship of Traffic and Floor Space Use in CBD; "Highway Research Record No. 114

6. Harper and Edwards; "Geneation of Person Trips by Areas with the CBD; "Highway Research Board No. 253

7. California Department of Transportation; Progress Report on Trip Ends Generation (All Reports)

8. Wilber Smith and Associates; An Access Oriented Parking Survey for the Boston Metropolitan Area

9. RTKL Associates, Inc.; Trip Generation Data; Sept.-Oct. 1976

FIGURE I-1

Trip Generation Data Sources

r^2 = Squared coefficient of correlation;

SE = Standard error of the estimate;

S = Size measure, usually gross area in 1000's of square feet.

Other notation is defined in the text.

In the analysis, hypothesis tests were performed to ascertain if a statistical basis existed for combining (or conversely, for maintaining the independence of) various classification groups. Tests were conducted using the R(I), where is was assumed that these measures were normally distributed. Generally, the "student's" t statistic was used, since most of the groups qualify as small samples having less than 30 points.

OFFICE GENERATION

(1) (II.B.2) Three categories of generation were examined. The first group consists of Local Use Buildings utilized as offices by doctors, lawyers, brokers, certain governmental agencies such as post offices and motor vehicle departments, and similar tenants. Threse generators are characteristically smaller than 200,000 square feet in size and produce an average of 5.4 person trips per hour per 1000 square feet. Some uses such as post offices may generate up to 15 trips per hour per 1000 square feet. Generation tends to decrease as building size increases.

(2) (II.B.3/II.B.4) A second grouping consists of Headquarters Buildings used as offices by insurance, banking and similar corporate entities, and all buildings over 400,000 square feet in size. These buildings produced 1.3 person trips per hour per 1000 square feet.

(3) (II.B.4) The third group consists of Mixed Use Buildings having a mix of private offices, as wellas tenants from the other two groups. Characteristically, these buildings are less than 400,000 square feet in size, and produce 1.8 person trips per hour per 1000 square feet.

RETAIL GENERATION

(1) (III.B.2) Five retail trip generation groups were identified, as follows:

- Specialty Retailing: Generally small, specialized, individual stores with gross areas of 20,000 square feet or less; average hourly person trip generation per 1000 square feet = 29.6

- Neighborhood Shopping Centers: Small, local shopping centers, usually with a supermarket, and having gross areas of 100,000 square feet or less; average hourly person trip generation per 1000 square feet = 11.9

- Community Shopping Centers: Medium sized, more diverse facilities with gross areas between 100,000 and 200,000 square feet; average hourly person trip generation per 1000 feet = 7.2

- Normal Retailing: Large, urban department stores with diversified retailing, and having gross areas ranging from about 200,000 to 1,000,000 square feet; average hourly trip generation per 1000 square feet = 5.1

- Regional Shopping Centers: Large, suburban facilities with highly diversified retailing, and having gross areas ranging from 200,000 square feet and more; average hourly person trip generation per 1000 square feet = 4.7

(2) (III.B.3) Under average conditions, the average hourly trip generation per 1000 square feet (R) is inversely proportional to gross area (S), with an approximation given by -

$$\bar{R} = 100 / \sqrt{S}$$

(3) (III.B.4) Data cited by Zupan tends to support generations rates computed herein for all three types of shopping centers, although some ambiguity does exist for community shopping centers due primarily to differences in the size parameters in the two data sets.

(4) (III.B.5) Saturday rates appear to be substantially higher than weekday rates for specialty retailing, and slightly higher for normal retailing; these results are based on very limited data.

(5) (III.B.6) Since sales area averages about 75% gross area, trip generation rates based on sales area will be about 33% higher than those based on gross area.

FOOD-RELATED GENERATION

(1) (IV.B.2) Three food-related groups were identified as follows:

- Fast Food, Carry-Out: Establishments characterized by a substantial amount of carry-out business, although they may have some seating usually without table service; seating is less than 100; examples include drive-ins, carry-out delis, sandwich shops. Average hourly person trip generation equals 128.4 trips per 1000 square feet and 3.1 trips per seat.

- <u>Fast Food With Service</u>: Establishments specializing in fast food service, but with less emphasis on carry-out business; often have counter seating, as well as table seating, and service; seating is about 100-200; examples include cafeterias and luncheonettes; average hourly person trip generation equals 47.6 per 1000 square feet and 1.4 per seat.

- <u>Full Service</u>: Full service restaurants with table seating and service, and often bars and lounges; seating ranges from about 100 to 300 or more; average hourly trip generation equals 11.5 trips per 1000 square feet and 0.43 trips per seat.

(2) (IV.B.3) No differences were found between generation rates for urban versus suburban locations; the mix of pedestrian versus other modes would obviously be different.

(3) (IV.B.4) Weekend (generally Saturday) generation is usually higher than weekday generation; the relationship depends on the magnitude of the weekday geneation, and is given by:

$$\left[\begin{array}{c}\text{Number of}\\ \text{Weekend Trips}\\ \text{Per Average Hour}\end{array}\right] = 2.73 \left[\begin{array}{c}\text{Number of}\\ \text{Weekend Trips}\\ \text{Per Average Hour}\end{array}\right]^{.084}$$

(4) (IV.B.5) Trips per seat tends to be a more reliable predictor for the fast food, carry-out facilities, while trips per 1000 square feet tends to be better for the fast food with service group; either measure will suffice for the full service restaurants; the number of seats per 1000 square feet decrease from 38 for the fast food, carry-out to 30 for the full service.

PARKING GENERATION

(1) (V.D.) Average hourly person trip generation per parking space, for various types of facilities, is as follows:

Type	Range
Metered Curb	2.1 - 3.6
Unmetered Curb	0.8 - 1.4
Average Curb	1.3 - 2.3
Parking Lot	0.6 - 1.1
Parking Garage	0.4 - 0.6
Average - Off Street	0.5 - 0.9

(2) (V.D.) Good estimators for parking generation are as follows:

	Average Hourly Person Trips Per Parking Space
Off Street	0.6
Curb	2.0

RESIDENTIAL GENERATION

(1) (VI.2.a) Single family dwellers have an average 24-hour person trip generation per dwelling unit = 15.6

(2) (VI.3.b) Apartment dwellings have an average 24-hour person trip generation per dwelling unit = 8.1; no significant difference existed between urban and suburban generation.

(3) (VI.2.b/VI.3.c) Single family dwellings are characterized by 3.7 residents per dwelling unit, while apartment exhibited 1.8 residents per unit; these factors are reliable for relating trips per dwelling unit and trips per resident.

(4) (VI.3.d) There is no significant difference in trip generation per resident between single family and apartment dwellings; average 24-hour person trip generation per resident = 4.6

(5) (VI.3.e) Large single family and apartment complexes tend to internalize some trips; the relationship is:

$$\left[\text{24-Hour Person Trips}\right] = 7.21 \left[\text{Number of Residents}\right]^{0.92}$$

(6) (VI.4.a) Suburban hotels/motels exhibit an average 24-hour person trip generation per occupied room = 13.4; based on severly limited data, urban hotels/motels generate 1.6 person trips per hour per 1000 square feet.

(7) (VI.4.b) Larger suburban hotels/motels tend to stimulate some trips - probably due to expanded services such as

restaurants and convention rooms; the relationship was found to be:

$$\left[\begin{array}{c}\text{24-Hour}\\ \text{Person Trips}\end{array}\right] = 12.05 \left[\begin{array}{c}\text{Number of}\\ \text{Occupied Rooms}\end{array}\right]^{1.02}$$

II. CATEGORY A - OFFICES

A. The Category A Data Base:

A total of 75 different office building sites were examined. Of this 75, 57 were considered to be suitable for further analysis. The 18 sites not included in subsequent analysis were excluded because measures of building size were not available. The 57 site data set contains three buildings surveyed by RTKL during September and October, 1976; all other data is from secondary sources.

Due to widely varying differences in the periods of counts associated with the secondary source data, it was necessary to adjust most of the person trip data. Typically the counts were either of 24 hours duration, or of 12 hours or less. As required, existing daily temporal distribution information was used to adjust data to consistent 12-hour counts corresponding to a period from 7:00 AM to 7:00 PM. All data, in its original form, applied to weeday generation. The 12-hour counts were then divided by 12 to obtain average hourly person trip generation.

The data points used in the Category A analyses are tabulated in Table 1 of the Appendix to this report.

B. Data Analysis - Category A

1. Overview

The Category A data set is plotted in Figure II-1. The average hourly person trip generation is plotted against the building size measure. Although the data exhibits a substantial amount of scatter, several trends do emerge, as follows:

(1) The highest generation is associated with buildings that are less than 200,000 square feet;

(2) Larger office buildings - those of 400,000 square feet or more - are consistantly low generators; and

(3) The remaining buildings tend to cluster in areas that combine characteristics of the other two groups.

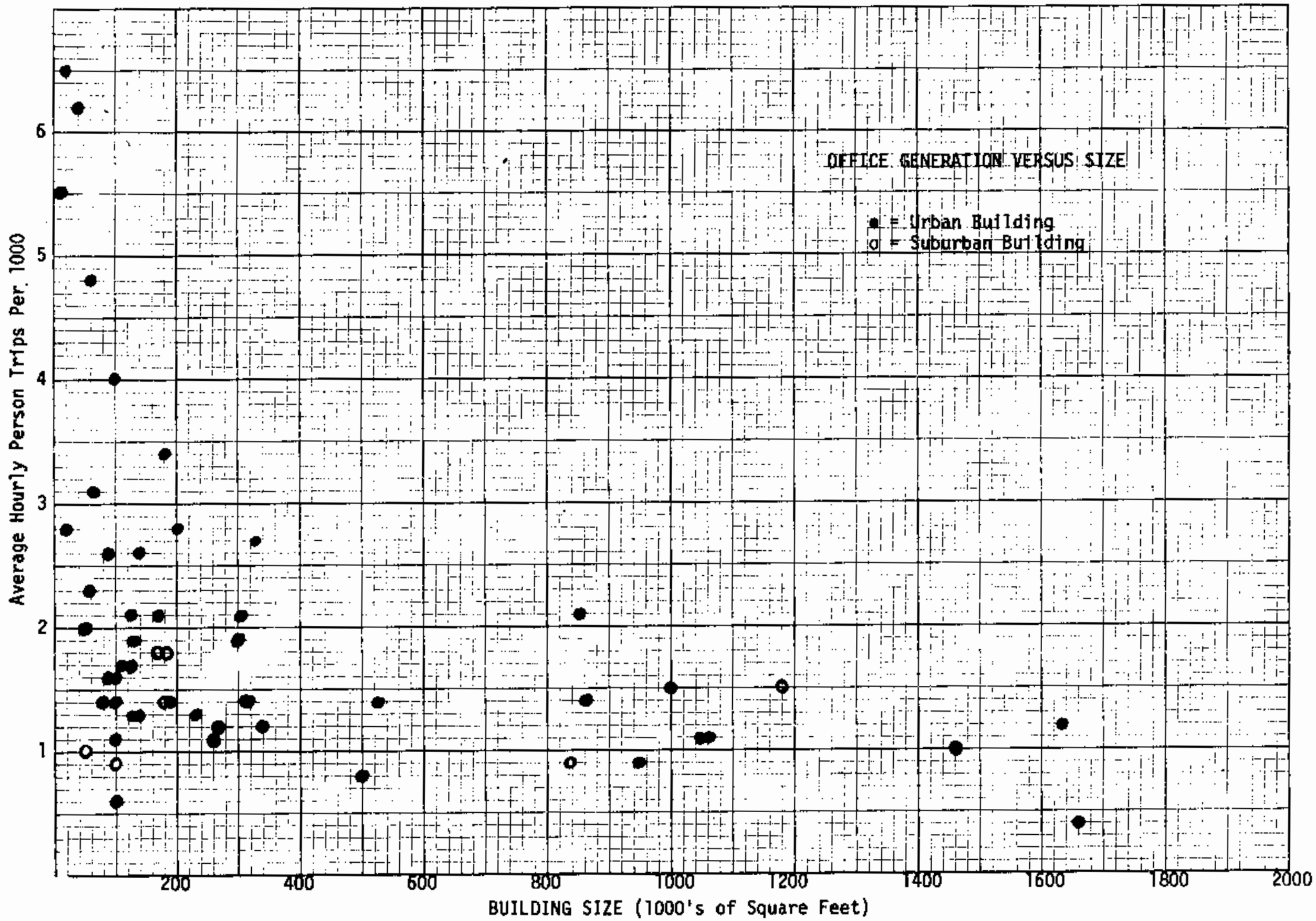


FIGURE II-1

Office Generation Versus Size

In the following sections, each of these groups will be examined separately.

(2) Local Use Buildings

All buildings that have average hourly person trip generation rates of 3.0 trips or more per 1000 square feet are also less than 200,000 square feet in size. On closer examination, these sites were found to have the following uses:

Site	Size (1000 ft.^{2})	Hourly Trips Per 1000 ft.^{2}	Use
A105	59	4.8	Unspecified Local Use
A110	100	4.0	Stockbrokers
A128	66	3.1	(Unknown)
A129	184	3.4	Municipal Building
A133	18	7.2	City Hall
A134	15	14.6	Motor Vehicles Department
A135	36	14.6	Post Office
A144	10	5.5	Medical Office
A145	39	6.2	Medical Office
A146	20	6.5	Medical Office

As the list shows, nearly all the sites can be classified as public, or Local Use Buildings having tenants that serve the public, such as doctors, lawyers, governmental agencies, etc.

Two of the sites qualify as outliers, generating trips at a rate far exceeding even the other Local Use Buildings. These two are the motor vehicles and post offices, each of which generate an average of 14.6 trips per hour per 1000 square feet.

Also, site A128 cannot be verified as a Local Use Building, and does appear to be more nearly related to another usage grouping.

Excluding these three data points, the remaining Local Use sites result in the following statistics:

	Average Hourly Trips Per 1000 $ft.^2$
N	7
$\bar{R}$	5.4
S(R)	1.4
V	0.3

It would appear that the generation rate for Local Use Buildings decreases as building size increases. This would appear to be a reasonable situation - as building size increases, less intensive uses may be attracted, in some cases, related uses, such as pharmacies in buildings of doctors offices, would tend to reduce the trip rate per 1000 square feet, while not generating additional trips.

Within the narrow range specified, the relationship between generation and size has the following form:

$$\text{Average Hourly Trips Per 1000} = \frac{18.16}{\text{Size } (1000 \text{ ft.}^2)^{0.32}}$$

which has an $r^2 = 0.946$, and can be tabulated as follows:

Size (1000 $ft.^2$)	Hourly Trips Per 1000 $ft.^2$)
10	8.7
25	6.5
50	5.2
100	4.2
200	3.4

In summary, Local Use Buildings are small - 200,000 square feet or less; are used for offices by doctors, lawyers, brokers, government agencies and similar tenants; generate an average of 5.4 trips per hour per 1000 square feet depending on size; and for some exceptional uses can generate up to about 15.00 hourly trips per 1000 square feet.

3. Headquarters Buildings

Reference to Figure II-1 indicates that larger buildings - those 400,000 square feet and above - generally have trip generation rates between 0.5 and 2.0 hourly trips per 1000 sq. ft.. The following list of these sites will allow closer examiniation of the data:

Site	Size (1000 ft.^{2})	Hourly Trips Per 1000 ft.^{2}	Use
A103	1180	1.5	Unspecified
A104	836	0.9	Unspecified
A107	1634	1.2	Headquarters (Unspec.)
A108	1048	1.1	Headquarters (Unspec.)
A118	525	1.4	Mixed Use
A121	949	0.9	Banking Headquarters
A148	1460	1.0	Banking Headquarters
A149	852	2.1	Banking Headquarters
A150	500	0.8	Insurance Headquarters
A151	1060	1.1	Insurance Headquarters
A152	1000	1.5	Insurance Headquarters
A153	1660	0.4	Government Building
A154	863	1.4	Governement Building

Examination of the list indicates that most of the buildings in this category are used as headquarters by tenant groups for functions such as banking and insurance administration and similar activities. These functions tend to limit contact with the general public. Also, large building size tends to internalize many employee trips due to the provision of food and other employee services within the building. Hence, the combined affect of limited employee, as well as non-employee, trips external to the buildings results in a low generation rate.

The data for headquarters result in the following statistics:

	Average Hourly Trips Per 1000
N	13
$\bar{R}$	1.2
S(R)	0.4
V	0.4

Although it appears that the generation rate decreases slightly as building size increases, a curve through the data points could not be shown to have a slope significantly different from zero; a zero slope indicates no relationship between generation rate and building size.

4. Mixed Use Buildings

In Figure II-1, after partitioning the Local Use and Headquarters Buildings, there remains a cluster of data for sites which are characteristically less than 400,000 square feet in size, and generate 3.0 or fewer hourly trips per 1000 square feet.

With some exceptions, all the sites in this category can be classified as Mixed Use Buildings incorporating private office spaces, as well as space devoted to Local and Headquarters Uses. The mix of offices type would probably vary widely from building to building. Exceptions are as follows:

Site	Size (1000 $ft.^2$)	Hourly Trips Per 1000 $ft.^2$	Use
A112	100	0.6	Insurance Headquarters
A115	90	2.6	Corporate Headquarters
A116	109	1.7	Corporate Headquarters
A119	226	1.3	Corporate Headquarters
A123	127	1.3	Insurance Headquarters

The listing above is provided to illustrate that the Mixed Use category of buildings may include elements from the other two groups. That is, some buildings under 400,000 square feet in size may be used as headquarters. Hence, some consideration of specific conditions should be made when using these data.

As a group, the Mixed Use Building group results in the following summary statisitics:

	Average Hourly Trips Per 1000 $ft.^2$
N	35
$\bar{R}$	1.8
S(R)	0.6
V	0.4

the statistics, resulting from a breakout of the known Headquarters Buildings listed above, are:

	Average Hourly Trips Per 1000 $ft.^2$ Buildings under 400,000 $ft.^2$)	
	Mixed Use	Headquarters
N	30	5
$\bar{R}$	1.8	1.5
S(R)	0.6	0.7
V	0.3	0.5

The basic Mixed Use Building statisitics remain virtually unchanged. Their predictability, measured by V, is slightly improved.

Using a "student's" t test to examine the Null Hypothesis that the two distributions above are not different yields:

t (computed)	= 0.98
t (0.95,33)	= 1.70

and the Null Hypothesis can be accepted; the two groups are not different.

A "student's" t test to determine if all Mixed Use Generation is the same as Headquarters Generation produced the following results -

t (computed)	= 3.27
t (0.99,46)	= 2.41

and the Null Hypothesis must be rejected at the 1% level of significance; the two groups are different.

Finally, a test was made to determine if the 30 Mixed Use Sites differed from all known Headquarters Buildings - 18 sites. The data used were -

	Average Hourly Trips Per 1000 ft.^{2}	
	Mixed Use	Headquarters
N	30	18
$\overline{R}$	1.8	1.3
S(R)	0.6	0.5

which yield the following test results:

t (computed)	= 2.91
t (0.99,46)	= 2.41

The test indicates that the Null Hypothesis must be rejected at the 1% level of significance.

III. CATEOGRY B - RETAIL

A. The Category B Data Base

A total of 135 retail person trip generation data points were examined. Of the 135 points, 107 covering 96 different sites were considered to be suitable for inclusion in the analyses described in subsequent sections; the other data points were rejected due to incompleteness, incompatibility or similar problems.

The person-trip data for each primary and secondary site were converted to average person-trips per hour by dividing daily trip generation data by applicable hours of operation for the retail facility. These measures were then used to compute the average hourly person-trips per 1000 square feet for each site. Where data were available, measures for weekday and Saturday generation, and for gross area and sales area rates, were computed.

The data points used in the Category B analyses are provided in Table 2 of the Appendix to the report. A profile of the data set is shown in Figure III-1.

B. Data Analysis - Category B

1. Category B Classification Groups

The basic statistics associated with the data classifications shown on Figure III-1 are tabulated in Figure III-2. In Classifications I and II, the data collected by RTKL is treated separately, so that it can serve as a check on the validity of the data obtained from secondary sources.

2. Hypothesis Tests for Classification Groups

a. Classification I - RTKL Points versus Other Source Points

For Class I (excluding RTKL points) and Class I (RTKL points only) distributions, the Null Hypothesis that the two groups are the same is tested using a one-third "student's" t test at the 5% level of significance, the results are:

$$t\ (\text{computed}) = 0.87$$
$$t\ (0.95, 6) = 1.94$$

Since $0.87 < 1.94$, accept the Null Hypothesis - there is no significant difference between the groups.

Hence, the data collected for normal retailing sites (essentially large diversified department stores in urban areas) by RTKL supports the validity of similar measures obtained from secondary sources. The combined statistics for Classification I are:

$$N = 8,$$
$$\overline{R} = 5.1,$$
$$S(R) = 1.0, \text{ and}$$
$$V = 0.2.$$

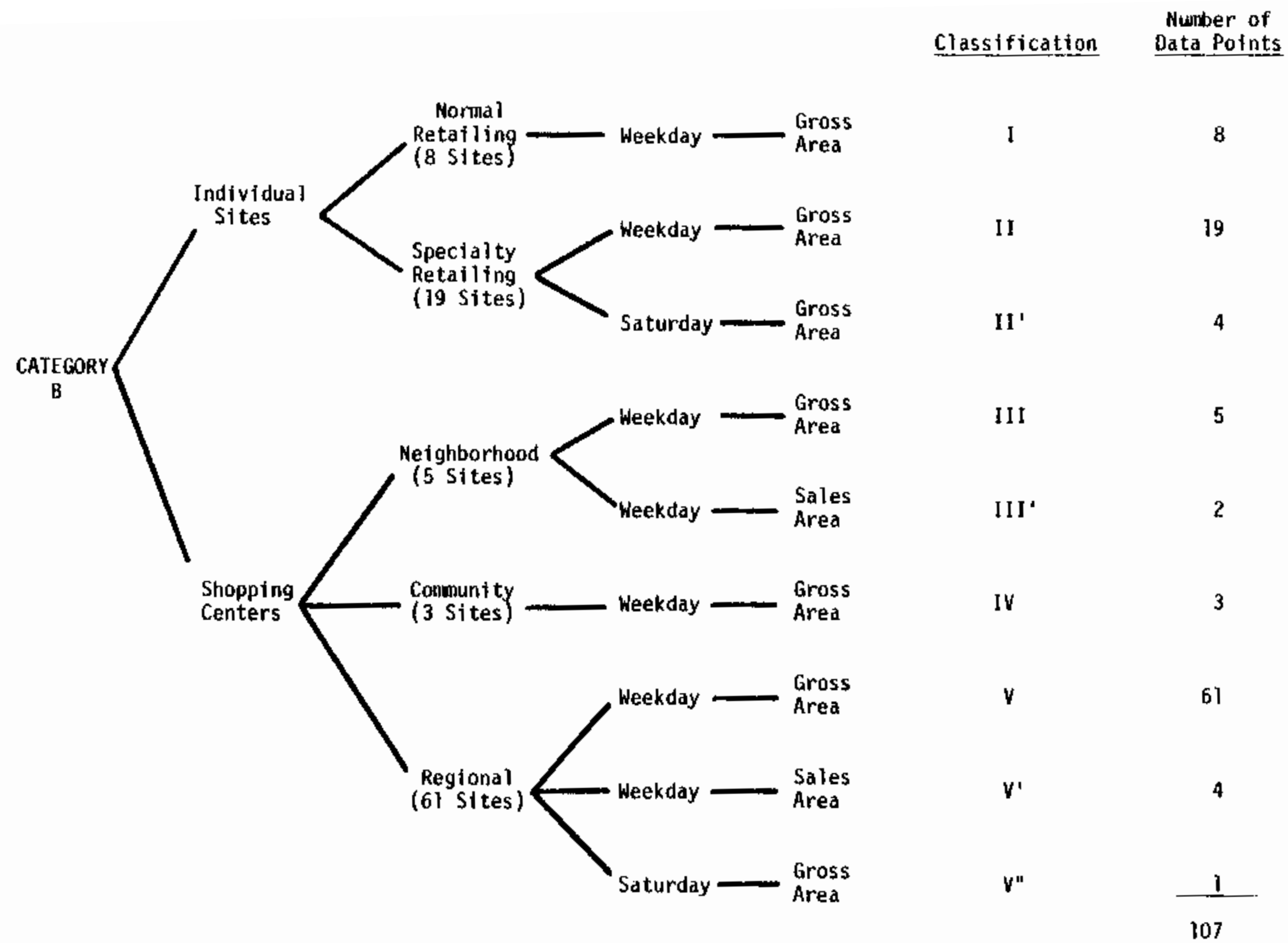


Figure III-1

PROFILE OF CATEGORY B DATA BASE

Classification	N	R	S(R)	V
I (Exc. RTKL Points)	5	4.8	1.2	0.3
I (RTKL Points Only)	3	5.5	0.2	0.04
II (Exc. RTKL Points)	9	27.4	4.8	0.2
II (RTKL Points Only)	10	31.5	19.3	0.6
II'	4	51.0	9.2	0.2
III	5	11.9	7.3	0.6
III'	2	13.0	4.2	0.3
IV	3	7.2	2.4	0.3
V	61	4.7	2.1	0.4
V'	4	4.9	1.9	0.4
V"	1	4.8	-	-

FIGURE III - 2

BASIC STATISTICS FOR
CATEGORY B CLASSIFICATION GROUPS

b. <u>Classification II - RTKL Points Versus other Secondary Source Points</u>

For II (excluding RTKL points) and II (RTKL points only) distributions, the Null Hypothesis is that the two groups are not different. Using a one-tailed test at the 5% level of significance:

t (computed) = 0.59
t (0.95,17) = 1.74

Since 0.59 $<$ 1.74, accept the Null Hypothesis - there is no difference between the groups.

Acceptance of the Null Hypothesis was influenced by the large variance found in the sites measured by RTKL. This variance, in turn, resulted from the wide spread of generation rates - R(312) = 3.1 for a small men's store to R(314) = 67.2 for a small gift shop. For data collected from secondary sources the range was much smaller - from R(42) - 21.0 to R(36) = 35.7 for a variety of sites located primarily in the New York City area. The RTKL data, while it supports the mean generation rate for specialty retailing, points to the requirement for adjustmenet of this mean rate to suit local conditions or other influencing factors.

The combined statistics for Classification II are:

N = 19,
$\overline{R}$ = 29.6,
S(R) = 14.2, and
V = 0.5.

c. <u>Classifications II, III and IV - Shopping Centers</u>

Classifications II, III and IV represent shopping centers - neighborhood, community and regional, respectively. In this subsection, hypothesis test results for significant differences between these groups are conducted. The results are as follows:

<u>Null Hypothesis: III = IV</u>

t (computed) = 2.05
t (0.95,6) = 1.94 (5% level)
t (0.99,6) = 3.14 (1% level)

Reject Null Hypothesis at 5% level and accept Null Hypothesis at 1% level of significance - two groups are probably different.

Null Hypothesis: IV = V

t (computed) = 10.44
t (0.99,62) = 2.66 (1% level)

Reject Null Hypothesis at 1% level of significance - groups are different.

Null Hypothesis: III = IV

t (computed) = 16.30
t (0.99,64) = 2.66

Reject Null Hypothesis at 1% level of significance - groups are different.

Hence, while Classifications III and IV could be similar, the conclusion is that the three groups of shopping center types represent three different trip generation land uses.

d. Classification I Versus Classification V

The similarities, in terms of size and diversity, of Classification I urban department stores and Classification V suburban regional shopping centers prompts the testing of the Null Hypothesis that these two groups are not different, using a two-tailed test at the 5% level of significance.

t (computed) = 3.74
t (0.975, 57) = 2.00

Hence, the Null Hypothesis cannot be accepted at the 5% level of significance - the groups are different.

e. Summary of Hypothesis Tests for Differences of Means

In terms of weekday average hourly person trip generation per 1000 square feet of gross area, the retail data points can be subdivided into five classifications. The five classifications arranged in order of decreasing R are presented, along with summary statistics in Figure III-3. The column denoted by $\overline{S}$ gives the average gross area (in 1000 square feet) for sites in that classification.

From examination of Figure III-3, it can be concluded that a direct relationship exists between the extent of diversity and trip generation; that is the more diverse the retailing, the lower the rate, or conversely, the more specialized the retailing, the higher the rate, since a measure such as gross retail space tends to decrease as the retail activity to which an area is devoted becomes more specialized, an inverse relationship between size and generation seems to exist. This will be examined more closely in the next section.

Classification	$\bar{S}$	$\bar{R}$	S(R)
II. Specialty Retailing	20.3	29.6	14.2
III. Neighborhood Shopping Centers	45.3	11.9	7.3
IV. Community Shopping Centers	144.3	7.2	2.4
I. Normal Retailing	449.6	5.1	1.0
V. Regional Shopping Centers	544.6	4.7	2.1

FIGURE III - 3

Ranked Classification Groups For
Weekday, Gross Area Retail Trip Generation

3. <u>Relationships between Size and Generation</u>

The inverse relationship between size, S, and trip generation, R, can be seen in Figure III-3. A curve fitted to the average shown in Figure III-3 is as follows:

$$\bar{R} = 107.04/\bar{S}^{+0.51}$$

which has an $r^2 = 0.928$ and a standard error (modified) of 4.5. A tabulation of points on this curve is:

S	$\bar{R}$
10	33.1
20	23.2
40	16.3
80	11.4
160	8.0
320	5.6
640	4.0

Within each category, very little of the variance is explained by introducing a size parameter.

4. Comparison with Zupan Data

Zupan cites the following:

Shopping Centers	Size (1000's $ft.^2$)	N	$\bar{R}$
Neighborhood	$S < 100$	21	11.9
Community	$100 \leq S < 500$	44	8.4
Regional	$500 \leq S$	23	4.5

Standard deviations are not provided; hence, in the following analyses, it is assumed that the S(R) for the Zupan data is equal to that associated with comparable data cited in this report (called RTKL/KSA data).

Several cases are examined:

Case 1 - Zupan neighborhood shopping center data versus RTKL/KSA neighborhood shopping center data.

	N	$\bar{R}$	S(R)
RTKL/KSA	5	11.9	7.3
Zupan	21	11.9	7.3 (EST)

These distributions are obviously the same, which tends to support the secondary data collected and reported herein.

Case 2 - Zupan neighborhood shopping center data versus RTKL/KSA shopping center data for sites with gross area 100 square feet.

	N	$\bar{R}$	S(R)
RTKL/KSA	6	11.3	6.7
Zupan	21	11.9	6.7 (EST)

These distributions are also obviously the same which supports the neighborhood shopping center data cited herein.

Case 3 - Zupan community shopping center data versus RTKL/KSA community shopping center data.

	N	$\bar{R}$	S(R)
RTKL/KSA	3	7.2	2.4
Zupan	44	8.4	2.4 (EST)

Using a one-tailed "student's" t test with a 1% level of significance -

t (computed)	=	0.82
t (0.99,45)	=	2.41

and the hypothesis that the two distributions are the same must be rejected. This result must be considered suspect because of the small number of RTKL/KSA data points and the need to use the associated standard deviation.

<u>Case 4</u> - Zupan community shopping center data versus RTKL/KSA shopping center data for sites with gross area between 100 and 500 square feet.

	N	$\bar{R}$	S(R)
RTKL/KSA	34	5.3	2.5
Zupan	44	8.4	2.5 (EST)

Using a one-tailed test with a -statistic at the 1% level of significance -

(computed)	=	5.43
(0.99)	=	2.33

and the Null Hypothesis is rejected.

<u>Case 5</u> - Zupan regional shopping center data versus RTKL/KSA regional shopping center data

	N	$\bar{R}$	S(R)
RTKL/KSA	61	4.7	2.1
Zupan	23	4.5	2.1 (EST)

Using a two-tailed test with a -statistic at the 5% level of significance -

(computed)	=	0.39
(0.975)	=	1.96

and the Null Hypothesis is accepted - the distributions are the same.

<u>Case 6</u> - Zupan regional shopping center data versus RTKL/KSA shopping center data for sites having gross areas of 500 square feet or more.

	N	$\bar{R}$	S(R)	
RTKL/KSA	28	4.3	1.5	
Zupan	23	4.5	1.5	(EST)

Using a two-tailed "student's" t test at a 5% level of significance -

t (computed) = 0.46
t (0.975,49) = 2.01

and the Null Hypothesis is accepted.

In summary, the Zupan data supports the secondary data collected for this report for both neighborhood and regional shopping centers. For community shopping center data, the results are ambiguous, although the data classification tends to be supported. Neither of these conclusions, however, should be viewed as proving or negating the validity of the data reported herein, since the absence of variation measures for the Zupan data prevent more reliable tests.

5. Weekend Versus Weekday Generation

Only four data points exist to compare weekend and weekday generation rates. The data are summarized below:

Site	Classi-ficaton	R(I) Weekday	R(I) Weekend	Percent Increase
B201	II	35.7	44.7	25.2
B220	II	--	56.1	--
B206	II	25.6	61.0	138.3
B209	II	23.5	41.8	77.9
B513	V	4.5	4.8	6.7

The data are very limited and any quantitative conclusions drawn from these data must be considered very tentative. However, it does appear that Saturday rates are higher than weekday rates, with specialty retailing (B201, B206, B209) showing substantially higher generation than the single typical normal retail site (B513 - Regional Shopping Center).

6. Gross Area Generation Versus Sales Area Generation

Appropriate data are summarized on the following page:

Site	Area-1000's ft.^{2} Gross	Sales	Decrease
B301	35.8	27.1	24.3
B302	42.2	35.4	16.1
B501	998.0	884.0	11.4
B502	1750.0	1250.0	28.6
B503	527.7	321.9	39.0
B504	1510.2	1144.4	24.2

On the average, sales area represents about 76.1% of the gross area; or trip generation rates based on sales area should be about 31% higher than those associated with gross area. Note that there is no change in the volume of trips, but only in the size parameter used to compute trip rates.

IV. CATEGORY C - FOOD

A. The Category C Data Base

A total of 60 food-related person trip generation data points were examined. Two, of the 60 points were excluded from subsequent analysis due to incompatibility of their associated size parameter. Hence, the analyses were conducted using 58 data points covering 23 different sites.

The measure subjected to analysis was derived from the average hourly person trip generation; however, due to variations in counting periods and/or hours of operation, it was necessary to convert the raw data. The data were basically of three types, and were adjusted as follows:

(1) Counts of twelve hours or less generally corresponding to to hours of operation - data were converted by dividing the total person-trip counted by the period of the count in hours;

(2) Counts of 24-hour duration for sites with 24-hour operation - data were converted by assuming that 75% of

the trip generation occurred within a 12-hour period - the 24-hour counts were multiplied by 0.75 and divided by 12;

(3) Counts of 24-hour duration for sites with 12 hours or less operation - data were converted by assuming that 95% of the trip generation occurred within the period of operation - the 24-hour counts were multiplied by 0.95 and divided by the hours of operation, if known, or by 12, if unknown.

The average hourly measures were then used to compute hourly trip generation per 1000 square feet and per seat, for both weekday and weekend, depending on the availability of appropriate data.

The data points used in the Category C analyses are provided in Table 3 of the Appendix to this report. A profile of the data is shown in Figure IV-1.

B. Data Analysis - Category C

1. Category C Classification Groups

The basic statistics for the data classifications shown in Figure IV-1 are tabulated in Figure IV-2. In classifications I and III, the data points resulting from RTKL's surveys are treated separately so that they can serve as a check on the data obtained from secondary sources.

2. Hypothesis Tests for Differences of Means

In the following subsections, tests are conducted to determine if the classification groups as defined represent independent distributions. Tests are performed on weekday data sets only.

a. Classification I - RTKL Data Points Versus Secondary Data Points

Using the limited data, a "student's" t test gives the following results:

	Per 1000 $ft.^2$	Per Seat
t (computed)	0.42	1.26
t (0.95)	2.02	2.13

and the Null Hypothesis that the two groups are not different can be accepted at the 5% level of significance. The combined statistics for Classification I become -

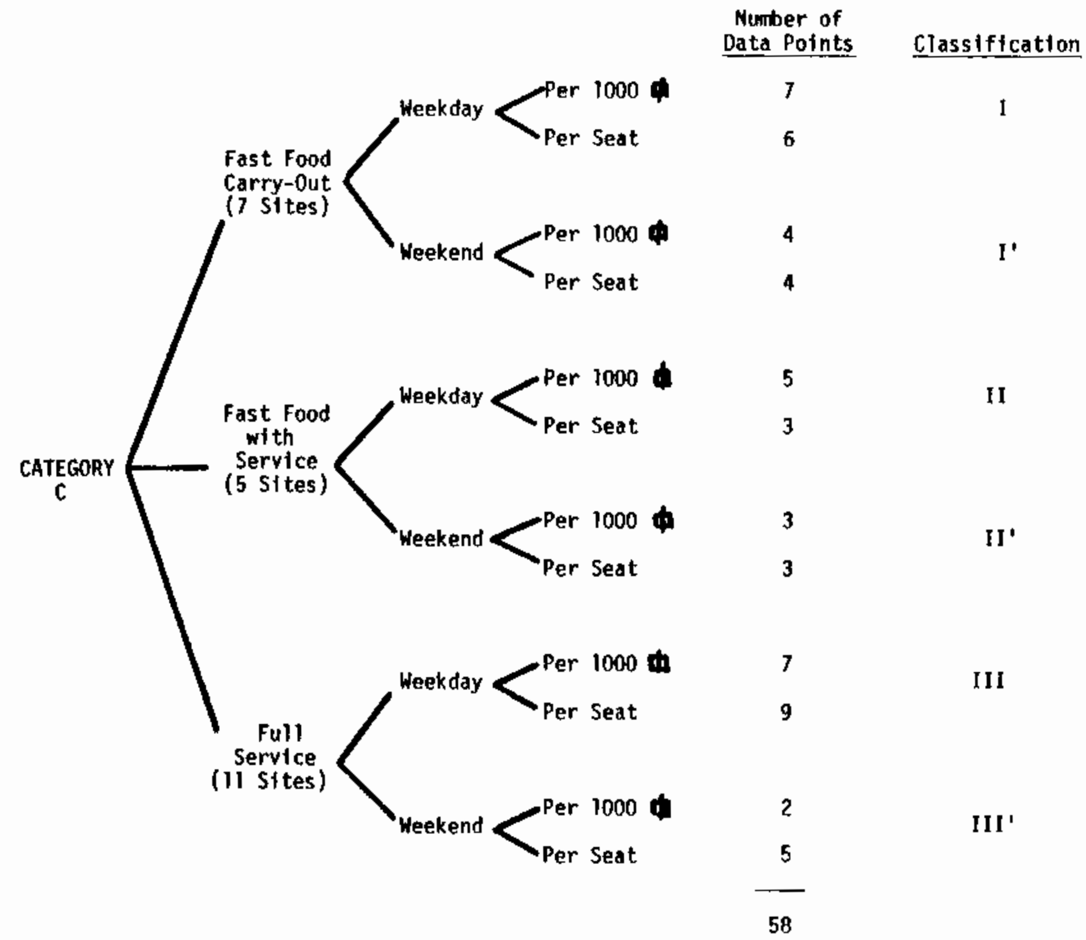


FIGURE IV-1

Profile Of Category C Data Base

Classification	N	$\bar{R}$	S(R)	V
Per 1000				
I (Exc. RTKL Points)	5	133.4	49.3	0.4
I (RTKL Points Only)	2	116.0	0.1	-
I'	4	134.1	54.9	0.4
II	5	47.6	6.7	0.1
II'	3	50.4	17.0	0.3
III (Exc. RTKL Points)	6	10.1	3.9	0.4
III (RTKL Points Only)	1	20.1	-	-
III'	2	15.2	4.9	0.3
Per Seat				
I (Exc. RTKL Points)	4	3.5	0.5	0.1
I (RTKL Points Only)	2	2.4	0.1	0.1
I'	4	4.0	1.3	0.3
II	3	1.4	0.4	0.3
II'	3	1.4	0.6	0.4
III (Exc. RTKL Points)	8	0.40	0.21	0.5
III (RTKL Points Only)	1	0.68	-	-
III'	5	0.78	0.19	0.2

FIGURE IV-2

Basic Statistics For Category C Classification Groups

		Per 1000 $ft.^2$	Per Seat
N	=	7	6
$\bar{R}$	=	128.4	3.1
S(R)	=	41.2	0.7
V	=	0.3	0.2

b. Classification III - RTKL Data Point Versus the Secondary Data Points

Only one primary data point exists, hence, the applicability of a valid statistical test is negated. However, the single primary data point lies within three standard deviations of the secondary mean for the "per 1000 $ft.^2$" data, and within two standard deviations based on "per seat" data. Hence, it can be concluded that the primary data point is from the distribution defined by the secondary data.

Based on this conclusion, the combined statistics for Classification III become -

		Per 1000 $ft.^2$	Per Seat
N	=	7	9
$\bar{R}$	=	11.5	0.43
S(R)	=	5.2	0.22
V	=	0.4	0.5

c. Classification I Versus Classification II

Using a "student's" t test against the Null Hypothesis that the two groups are the same -

		Per 1000 $ft.^2$	Per Seat
t (computed)	=	3.97	3.52
t (0.99)	=	2.76	3.00

and the Null Hypothesis must be rejected at the 1% level of significance. The other distributions are obviously different groups, as can be ascertained by inspection.

3. Urban Versus Suburban Generation

Using weekday data only, the distribution of urban versus suburban generation rates is examined within each classification.

a. Classification I

The data are as follows -

	Per 1000 ft.^{2}			Per Seat		
	N	$\bar{R}$	S(R)	N	$\bar{R}$	S(R)
Urban	5	139.1	44.2	4	3.0	0.7
Suburban	2	101.7	19.3	2	3.4	0.7

and the results of the "students" t test are -

		Per 1000 ft.^{2}	Per Seat
t (computed)	=	0.97	0.54
t (0.95)	=	2.02	2.13

The Null Hypothesis that the distributions are the same can be accepted at the 5% level of significance.

b. Classification II

The data are -

	Per 1000 ft.^{2}			Per Seat		
	N	$\bar{R}$	S(R)	N	$\bar{R}$	S(R)
Urban	4	14.1	4.4	7	0.48	0.20
Suburban	3	8.2	4.6	2	0.26	0.22

and the results of the "student's" t test are -

		Per 1000 ft.^{2}	Per Seat
t (computed)	=	1.46	1.18
t (0.95)	=	2.02	1.90

The Null Hypothesis is accepted at the 5% level of significance.

c. Classification III

The data are -

	Per 1000 ft.^{2}			Per Seat		
	N	$\bar{R}$	S(R)	N	$\bar{R}$	S(R)
Urban	4	14.1	4.4	7	0.48	0.20
Suburban	3	8.2	4.6	2	0.26	0.22

and the results of the "student's" t test are -

		Per 1000 ft.^{2}	Per Seat
t (computed)	=	1.46	1.18
t (0.95)	=	2.02	1.90

The Null Hypothesis is accepted at the 5% level of significance.

4. Weekday Versus Weekend Generation

For the data examined, the average hourly weekend generation, T(WE), was generally higher than the average hour weekday generation, T(WD). The relationship is dependent on the weekday rate, and is given by -

$$T(WE) = 2.73 \quad T(WD)^{0.84}$$

which has $r^2 = 0.942$ and a standard error modified = 48.0. This expression relates total average hourly volumes generated, and applied to the range

$$50 \leq T(WD) \leq 350$$

A tabulation of the curve is -

T(WD)	T(WE)
50	73
100	131
150	184
200	234
250	282
300	329
350	374

5. Size Parameter Characteristics

From examination of the relative dispersion measure, V, tabulated in Figure IV-2, the following can be concluded -

- Trips per seat is a more reliable predictor for Classification I;
- Trips per 1000 square feet is a more reliable predictor for Classification II; and
- Either trips per 1000 square feet or trips per seat can be used in Classification III.

The average number of seats per 1000 square feet decreases slightly as the classification increases from fast food, carry-out facilities to full service restaurants:

Class	Seats Per 1000 ft.^{2}
I	38.0
II	33.0
III	30.1

The last result is intuitively obvious, but it should be noted that the number of seats specified for Classification III facilities does not include those associated with bars or lounges.

V. CATEGORY D - PARKING

The material on parking generation of pedestrian trips was collected and examined by RTKL; most of the following presentation was developed from that material.

A. Parking Generation Model

A large percentage of pedestrian trips in an urbanized area include a transportation terminal as a trip end. Typical terminals include bus stops, subway and railroad stations, and parked vehicles or parking facilities. Pedestrian trip generation at bus stops, subways and similar facilities varys widely depending on local conditions, and can only be ascertained from analysis of patronage figures associated with the special facility of interest. Generation associated with parking, on the other hand, has been widely studied and the study results show that some trends can be used for prediction purposes.

The pedestrian generation potential of a parking facility can be expressed, in terms of factors that are commonly measured, as follows -

$$\bar{R} = \text{Person trip rate per parking space}$$

$$= 2 \times T \times O$$

where T = The parking space turnover rate, and
O = Average occupancy rate per parked vehicle.

In the formula, the factor, 2, is used because it is assumed that each parking action generates a trip from and a trip to the parking space. The turnover rate, T, reflects the efficiency of the parking space utilization, and is equal to the average number of vehicles using a parking space within a given time period on a typical weekday. Hence, the generation rate, R, will be expressed as vehicles per 12-hour period, then R will reflect person trips per space per 12-hour period. Total generation for facility is obtained by multiplying R by the number of parking spaces contained in the facility.

B. Turnover Rate

The utilization of parking space can depend on numerous factors, but is primarily influenced by the parking facility type. A full typology of parking facilities is as follows -

Curb

Metered

- 30 Minute
- one hour
- two hour
- greater than two hours

Unmetered

- 15 minute
- no time limit
- loading zone
- reserved

Illegal Curb

Off Street

Parking Lots

- public
- private

Parking Garages

- public
- private

Each of these facility types will exhibit different utilization characteristics. Numerous studies which address parking turnover at varying levels of detail have been conducted in most major cites. A representative collection of parking rates reported upon in these studies is shown in Figure V-1. Most of the turnover rates tabulated in Figure V-1 reflect a period of 10:00 AM to 6:00 PM on a typical weekday. Although the criteria are not explained in the source documents, it would appear that the time period was chosen to achieve a balance of peak and off-peak parking turnover.

Statistics, based on the data shown in Figure V-1, are as follows:

<table>
<tr><th></th><th colspan="2">CURB</th><th colspan="2">OFF STREET</th></tr>
<tr><th>Location</th><th>Metered Curb</th><th>Unmetered Curb</th><th>Parking Lot</th><th>Parking Garage</th></tr>
<tr><td>Boston, Mass.</td><td>3.27</td><td>2.56</td><td>1.45</td><td>1.14</td></tr>
<tr><td>Tampa, Fla.</td><td colspan="2">6.00</td><td colspan="2">2.35</td></tr>
<tr><td>Baltimore, Md.</td><td>--</td><td>--</td><td>--</td><td>1.4</td></tr>
<tr><td>Fresno, Calif.</td><td>--</td><td>--</td><td>4.0</td><td>1.8</td></tr>
<tr><td>Hartford, Conn.</td><td colspan="2">4.8</td><td colspan="2">1.2</td></tr>
<tr><td>Montgomery, Ala.</td><td>9.72</td><td>3.15</td><td colspan="2">1.41</td></tr>
<tr><td>Birmingham, Ala.</td><td>7.9</td><td>--</td><td colspan="2">1.3</td></tr>
<tr><td>Chattanooga, Tenn.</td><td>7.2</td><td>2.9</td><td>1.6</td><td>1.3</td></tr>
<tr><td>Anchorage, AK</td><td>5.8</td><td>1.8</td><td>1.6</td><td>0.6</td></tr>
<tr><td>Tulsa, Okla.</td><td>7.5</td><td>2.4</td><td>1.3</td><td>0.9</td></tr>
<tr><td>Manchester, N.H.</td><td colspan="2">3.3</td><td colspan="2">2.6</td></tr>
<tr><td>Lafayette, La.</td><td colspan="2">3.31</td><td colspan="2">1.25</td></tr>
</table>

FIGURE V - 1

Parking Turnover Rates
For Representative Cities

	Turnover Rate (T)	
	10:00 AM - 6:00 PM Weekday	
Metered Curb	6.9	
Unmetered	2.9	
Average - Curb		4.4
Parking Lot	2.0	
Parking Garage	1.2	
Average - Off-Street		1.7

Since the rates shown above apply to a typical eight-hour weekday period, a more useful measure might be the number of turnovers per hour; these adjusted rates are as follows:

	Turnovers Per Hour	
Metered Curb	0.86	
Unmetered Curb	0.33	
Average - Curb		0.55
Parking Lot	0.25	
Parking Garage	0.15	
Average - Off-Street		0.21

C. Vehicle Occupancy Rate

The vehicle occupancy rate is the average number of persons, including the driver, in each vehicle using a parking facility. Parking studies typically measure occupancy rate as a function of trip purpose, and (unfortunately) not as a function of parking facility type. Common trip purposes examined are the following:

- Work
- Shopping
- Personal Business
- Sales and Service
- Restaurants (to eat)
- Recreation
- Residential (home-based)

Occupancy rates cited in five representative sources are shown in Figure V-2.

D. Trip Generation Rates ($\bar{R}$)

Vehicle occupancy rates vary from 1.2 to 2.1 depending on trip purpose. Ignoring variation in turnover rates due to location, the range of average hourly trip generation per parking space ($\bar{R}$) for various parking facility types is as follows:

Source	Work	Shopping	Personal Business	Sales and Service	Restaurants	Recreation	Residential: Single Family	Residential: Apartments	Residential: Hotel	Other
Wilber Smith (Boston, Mass.)	1.3	1.7	1.4	1.3	-	2.0	-	-	-	1.4
Pushkarev & Zupan	1.2	2.0	-	-	2.5	-	1.6	1.4	-	-
California Dept. of Highways (10th Progress Report)	1.3	1.3 1.6	1.3	-	1.6 2.0	-	1.5	1.3	1.4	-
Wilber Smith (Baton Rouge, La.)	1.1	1.6	1.4	-	-	2.0	-	-	-	-
Wilber Smith (Lafayette, La.)	1.2	1.8	1.5	-	-	2.2	-	-	-	-
Average	1.2	1.7	1.4	1.3	2.0	2.1	1.6	1.4	1.4	1.4

FIGURE V - 2

Representative Vehicle Occupancy
Rates - By Trip Purpose

Parking Facility Type	Range for $\bar{R}$
Metered Curb	2.1 - 3.6
Unmetered Curb	0.8 - 1.4
Average - Curb	1.3 - 2.3
Parking Lot	0.6 - 1.1
Parking Garage	0.4 - 0.6
Average - Off Street	0.5 - 0.9

Furthermore, since long term, off street parking is usually associated with work trips and other trip purposes at the lower end of the vehicle occupancy range, a good predictor for off street parking would be -

$\bar{R}$ (off street) = Average hourly person trips per hour generated per off street parking space

= 0.6

Also, short term, curb parking is usually associated with shopping, restaurant and other trip purposes at the higher end of the vehicle occupancy range, so that a good predictor for curb parking would be -

$\bar{R}$ (curb) = Average hourly person trips per hour generated per curb parking space

= 2.0

These two factors can be modified, using additional information, to suit local, site-specific conditions.

VI. CATEGORY E - RESIDENTIAL

A. The Category E Data Base

Residential, or home-based, generation of person trips has been widely studied. In-depth research has shown that trip rates are based on various factors, primarily car ownership and family income levels. The examination contained herein does not attempt to duplicate this level of detail, but rather operates on an independent data set in order to obtain trip generation factors useful in pedestrian planning.

A total of 43 residential sites were examined, from which 39 were subsequently analyzed. The other four sites were excluded because the type of residence was unspecified and could not be

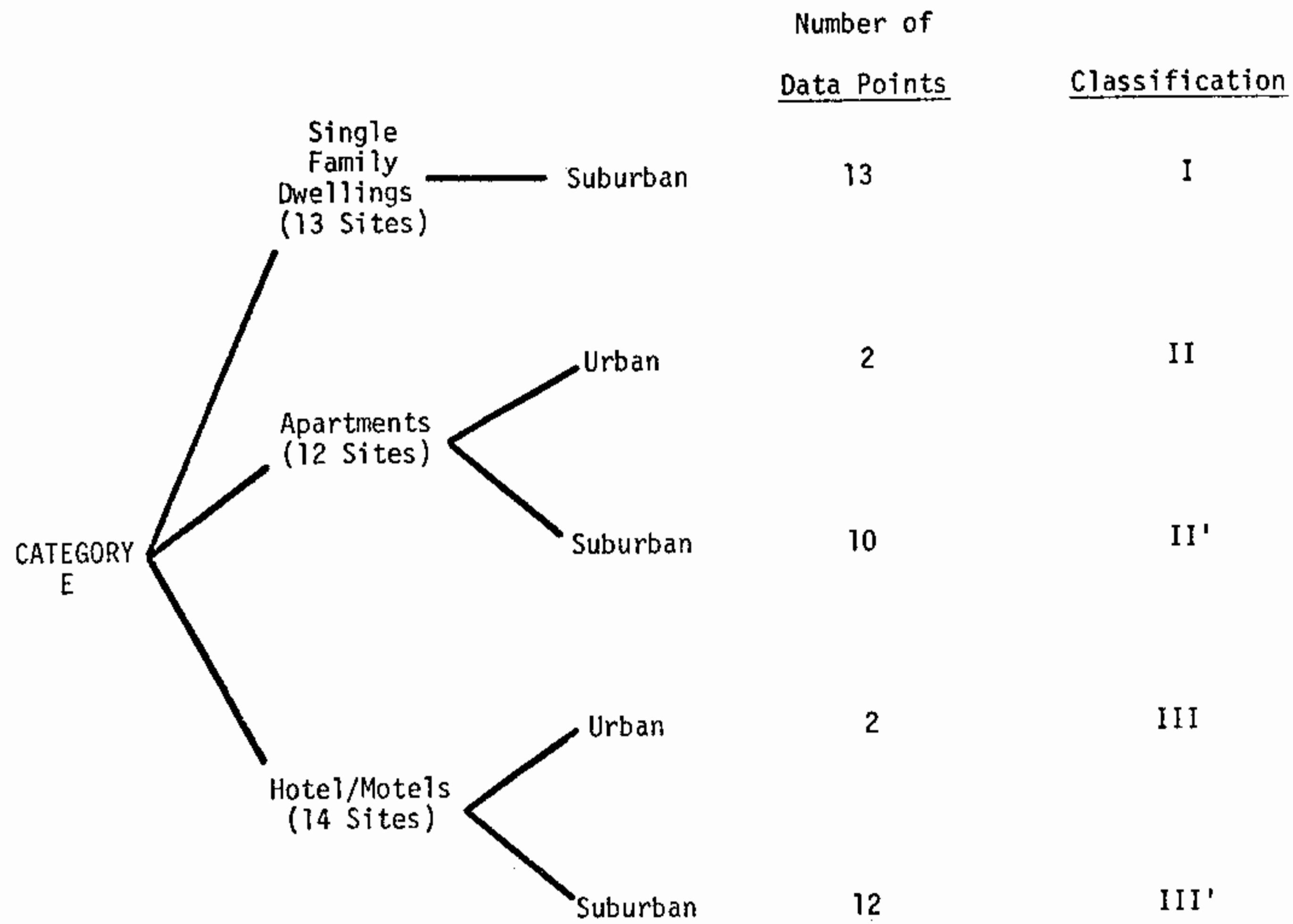


FIGURE VI-1

Category E Data Base Profile

classified. The data points for Category E analysis are provided in Table 4 of Appendix. A profile of the data set is shown in Figure VI-1.

For all single family dwellings and apartments, data was obtained in terms of trips per dwelling unit and trips per resident. All trip rates are given in person trips per 24-hour typical weekday, and all locations are suburban.

For hotels and motels, generation for all suburban sites is expressed in person trips per 24-hour period per occupied room; trips refer to a typical weekday. For the two urban sites, generation is measured in trips per 1000 square feet, and the periods of counting are as follows:

Site E301	10:00 AM - 6:00 PM	(8 hours)
Site E314	7:00 AM - 6:00 PM	(11 hours)

Classification		N	$\bar{R}$	S(R)	V
I	(Per Dwelling Unit)	13	15.4	2.8	0.2
I	(Per Resident)	13	4.3	0.8	0.2
II	(Per Dwelling Unit)	2	7.8	0.3	-
II	(Per Resident)	2	4.8	0.4	0.1
II'	(Per Dwelling Unit)	10	8.6	2.3	0.3
II'	(Per Resident)	10	4.6	0.9	0.2
*III	(Per 1000 Square Feet)	2	1.6	0.3	0.2
III'	(Per Occupied Room)	12	13.4	3.8	0.3

FIGURE VI - 2

Basic Statistics For
Category E Classification Groups

* All statistics based on 24-hour trip generation except Class III which is based on average hourly counts during the 10:00 AM to 6:00 PM time period.

B. Data Analysis - Category E

1. Category E Classification Groups

Basic statistics associated with the data classifications shown in Figure VI-1 are tabulated in Figure VI-2.

2. Class I - Single Family Dwellings

a. Adjusted Data

For the purposes of pedestrian planning, generation will usually be predicted for small clusters of single family dwellings. Therefore, an analysis was made on all data for which the number of dwelling units is 300 or less; this led to the exclusion of sites E101, E102 and E113.

For the revised Class I data set, the following statistics were obtained:

	24 Hour Person Trips	
	Per Dwelling	Per Resident
N	10	10
$\bar{R}$	15.6	4.3
S(R)	3.2	0.9
V	0.2	0.2

Comparison of the above results with those tabulated in Figure VI-2 shows very little change in the values. Also, examination of V indicates that either measure can be used for predicting generation.

b. Residents Per Dwelling Unit

The two primary measures, trips per dwelling unit and trips per resident, are related through the parameter, residents per dwelling unit. Analysis of the adjusted data set yeilds the following for X(I) equal to residents per dwelling unit for Site I.

$\bar{X}$ - 3.7
S(X) - 0.6

To test the validity of using 3.7 as a factor to relate generation by residents and dwelling units, a chi-squared Goodness of Fit test was made to compare two distributions - the "observed" number of trips per dwelling unit (as actually counted at each site) and the "expected" distribution obtained by multiplying the number of trips per resident at each site by 3.7. The results of the chi-squared test were -

$$\lambda^2 \text{ (computed)} = 3.3$$
$$\lambda^2 \text{ (0.95,9)} = 16.9$$

and the Null Hypothesis that the distributions are the same is accepted at the 5% level of significance.

Hence, the following relationship can be used to relate trip generation measures for single family dwellings -

$$\left[\text{Trips Per Dwelling Unit}\right] = 3.7 \left[\text{Trips Per Resident}\right]$$

c. Influence of the Size Parameter

Using the full data set, a curve relating total person trips per 24 hours to the total number of dwelling units for single family dwellings is -

$$\left[\text{Person trips Per 24 Hours}\right] = 17.39 \left[\text{Number of Dwelling Units}\right]^{0.98}$$

which has an r^2 of 0.989. One point, associated with Site E112, was an obvious outlier, and on closer examination was found to be related to a site in a low income neighborhood with a high number of residents per dwelling unit and low vehicular ownership. These factors contribute to the low trip generation rates measured, in computing the above curve, this outlier was excluded.

3. Class II - Apartments

a. Urban versus Suburban Generation

Using the statistics summarized in Figure VI-2 and a "student's" t test to evaluate the Null Hypothesis that there is no difference between urban and suburban generation for apartments yields -

	Per Dwelling Unit	Per Resident
t (computed)	0.39	0.28
t (0.95,10)	1.81	1.81

and the Null Hypothesis can be accepted at the 5% level of significance.

b. Adjusted Data Base

For the purpose of pedestrian planning, generation will usually be predicted for apartment complexes of 350 units or less. Therefore, an analysis was conducted on only those sites with 350 units or less (excluding sites E201, E202, and E203), and the following statistics were obtained:

	24 Hour Person Trips	
	Per Dwelling	Per Resident
N	9	9
$\bar{R}$	8.1	4.6
S(R)	2.2	1.0
V	0.3	0.2

c. Residents Per Dwelling Unit

Analysis of the adjusted data set for X(I) equal to residents per dwelling for Site I yields:

$\bar{X} = 1.8$
$S(X) = 0.4$

Applying a chi-squared Goodness of Fit test to the "observed" number of trips per dwelling unit and the expected number obtained by multiplying the observed number of trips per resident by 1.8 yields -

λ^2 (computed) = 3.6
λ^2 (0.95,7) = 14.1

so that the Null Hypothesis can be accepted. Hence, the following relationship can be used for apartment generation.

$$\left[\text{Trips Per Dwelling Unit}\right] = 1.8 \left[\text{Trips Per Resident}\right]$$

d. Single Family Dwellings Versus Apartment Generation Per Resident.

Generation per unit between single family and apartment dwelling is obviously different due to the residents per dwelling unit difference. However, the generation per resident is worthy and examination. The following data, using the adjusted data sets, apply -

	Single Family	Apartment
N	10	9
$\bar{R}$	4.3	4.6
S(R)	0.9	1.0

A "student's" t test results in the following -

t (computed) = 0.65
t (0.95,17) = 1.74

Hence, the Null Hypothesis that there is no difference can be accepted at the 5% level of significance.

The combined statistics for single family and apartment dwelling trips per resident, using the adjusted data sets, are -

	24 Hour Person Trips Per Resident
N	18
R	4.6
S(R)	0.8
V	0.2

e. Trip Generation Versus Number of Residents

A test was conducted of the notion that large clusters of single family dwellings and larger apartment complexes will tend to internalize some trips, using the combined data set of the previous subsection, the following relationship is obtained.

$$\left[\begin{array}{c}\text{24 Hour}\\\text{Person Trips}\end{array}\right] = 7.21 \left[\begin{array}{c}\text{Number of}\\\text{Residents}\end{array}\right]^{0.92}$$

which has an r^2 of 0.897. The tabulated values for this curve are -

Number of Residents	Number of 24 Hour Person Trips
200	952
400	1803
600	2620
800	3416
1000	4195

4. Class III - Hotels/Motels

a. Trip Generation

As shown in Figure VI-2, the basic statistics for Class III are:

	Urban (Trips Per 1000 ft.^{2})	Suburban (Trips Per Occupied Room)
N	2	12
$\overline{R}$	1.6 (Per Hour)	13.4 (24 Hours)
S(R)	0.3	3.8

b. Generation Versus Size (Suburban)

It can be postulated that larger hotel/motel facilities will have services such as restaurants that generate trips; this notion has to be examined against the condition that these same services may operate to internalize some trips. Analysis of the 12 suburban data points results in the following relationship -

$$\left[\begin{array}{c}\text{24 Hour}\\\text{Person Trps}\end{array}\right] = 12.05 \left[\begin{array}{c}\text{Number of}\\\text{Occupied Rooms}\end{array}\right]^{1.02}$$

which has an r^2 of 0.959. Hence, it appears that the larger facilities do stimulate some trips. Tabulated values for the curve are:

Number of Occupied Rooms	Number of Person Trips Per 24 Hours
50	652
100	1,321
250	3,364
500	6,822
750	10,317
1,000	13,835
1,500	20,922
2,000	28,057

VII. TEMPORAL DISTRIBUTION OF TRIPS

A. Introduction

Generation rates, presented, in previous sections, for office, retail, and food-related categories are expressed in terms of the average hourly number of person trips. Due to temporal variation of the genration, however, the average rate occurs only during a small portion of any given day. In this section, the temporal distribution of trip generation will be examined. These data will provide a basis for:

- Adjusting the average generation rate as a function of time; and

- Estimating average hourly, or daily, generaion based on limited count data (Calibration Measures).

In the following sections, specific sites are examined in the office, retail and food-related categories, also, temporal pedestrian movement on three street types is assessed. For the analysis, the streets were categorized as:

- Office Streets - The predominance of abutting land uses are office buildings with minimal significant retail activity;

- Retail Streets - The predominance of abutting land uses are retail establishments with minimal significant office or employment use, and

- Mixed Streets - The abutting land use consists of a mixture of significant office and retail space.

B. Office Distributions

Temporal trip volumes, expressed as percentages of 12-hour daily, weekday volumes, are presented in Figure VII-1. The figure clearly shows the morning, noon and evening peaks, and compares the office street volumes with office building generation. The data are summarized in Figures VII-1 and VII-2.

The data are summarized as follows:

- The morning peak hour occurs between 8:00 and 9:00 AM and has a magnitude 1.6 times the average hourly volume.

- The noon peak hour is fairly constant between 12 noon and 2:00 PM, and has a magnitude between 1.6 and 1.7 times the average hourly volume.

- The evening peak hour is constant between 4:00 and 6:00 PM, and has a magnitude 1.2 times the average hourly volume.

- The coefficient of variation, V, is reasonably constant throughout the 12-hour period, with the midday hours between 11:00 AM and 2:00 PM being favorable for calibration purposes.

- Office buildings exhibited less variance in the sample than office streets.

<u>Office Streets</u>

- The morning peak hour occurs between 8:00 and 9:00 AM, and has a magnitude 1.2 times the average hourly volume.

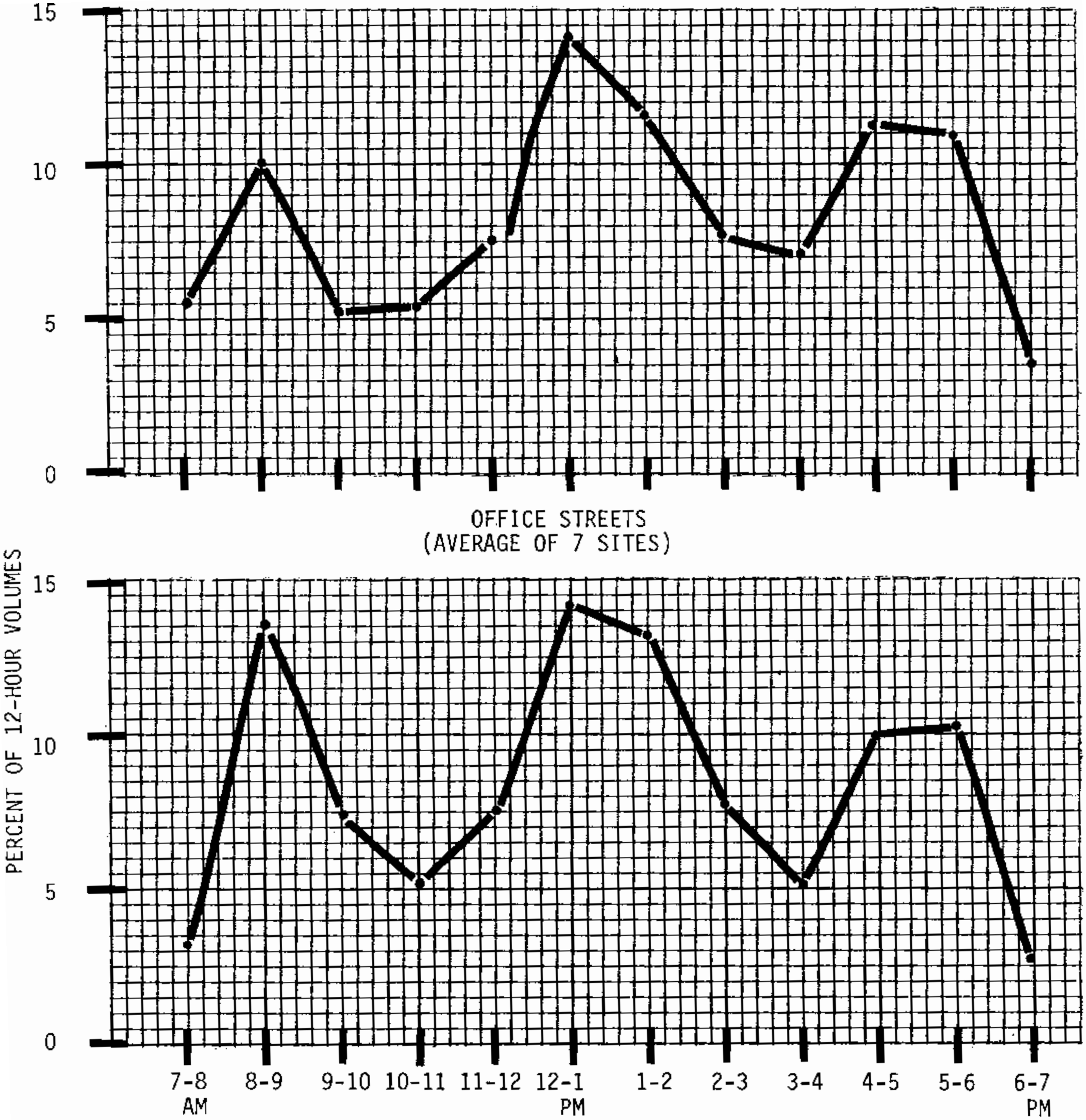
- The noon peak hour lasts from 12 noon until 2:00 PM and has a magnitude between 1.7 and 1.4 times the hourly average volume.

- The evening peak hour lasts from 4:00 to 6:00 PM, and has a magnitude between 1.4 and 1.3 times the average hourly volume.

- Based on the coefficient of variation, V, the most suitable time for calibration of trip volumes is between 12 noon and 2:00 PM.

- Generally, the office street volumes exhibited more variation in the sample than the office building volume.

Measurements based on hourly volumes will be substantially below the magnitude of short-duration "spikes" or "surges" in movement, due to the leveling or averaging effect of the longer count duration. It is of interest that volumes of 2.5 to 3.5 times the hourly average are not uncommon for short periods of time - usually occurring during one of the three major peak periods.



OFFICE BUILDINGS
(AVERAGE OF 8 SITES)

FIGURE VII-1

Temporal Trip Volumes Offices

	Office Streets				Office Buildings			
Time Period	Mean (%)	Std. Dev.	V	X	Mean	Std. Dev.	V	X
7 - 8 AM	5.6	2.5	0.4	0.7	3.2	1.5	0.5	0.4
8 - 9	10.1	4.7	0.5	1.2	13.5	2.7	0.2	1.6
9 - 10	5.2	1.1	0.2	0.6	7.5	2.1	0.3	0.9
10 - 11	5.4	2.2	0.4	0.6	5.3	0.9	0.2	0.6
11 - 12	7.5	2.5	0.3	0.9	7.5	1.3	0.2	0.9
12 - 1 PM	14.2	3.5	0.2	1.7	14.2	2.0	0.1	1.7
1 - 2	11.5	2.3	0.2	1.4	13.1	2.2	0.2	1.6
2 - 3	7.7	2.2	0.3	0.9	7.8	2.0	0.3	0.9
3 - 4	7.0	1.2	0.2	0.8	5.1	0.8	0.2	0.6
4 - 5	11.3	3.8	0.3	1.4	9.9	2.8	0.3	1.2
5 - 6	10.9	5.0	0.5	1.3	10.2	2.2	0.2	1.2
6 - 7 PM	3.6	1.6	0.5	0.4	2.7	0.2	0.1	0.3

FIGURE VII-2

Temporal Trip Volumes
Summary Data
Office Streets and Office Buildings

X = Multiple of Average Hourly Volume

C. Retail Distributions

This section treats two categories of retailing: (1) normal retailing - usually characterized as large, urban department stores; and (2) specialty retailing - the smaller stores and shops usually having a single product line such as clothing, shoes, books or gifts.

1. Department Stores

In Section III, trip generation rates for retailing were based on the average number of trips generated per hour of peration. In this section, however, due to variations in hours of operation and the necessity to compare sites directly at given points in time, only the generation between 10:00 AM and 6:00 PM at each site was considered. With one exception, this time period reflects the actual conditions used to derive the measures presented in Section III. For the single exception, generation during the period 9:30 AM to 10:00 AM was ignored.

A tabulation and graphic representation of the data is provided in Figures VII-3 and VII-4. As the figures indicate, departmenet stores have a peak between 12:00 noon and 1:00 PM with a magnitude of 1.7 times the average hourly volume. The coefficient of variation, V, for the sample is reasonably constant throughout the day, however, for calibration purposes counts will be more reliable during the 12:00 noon to 3:00 PM period.

Short duration "spikes" in the volumes could reach 3.0 times the hourly average during the noon peak hour.

Time Period	Department Stores			
	Mean (%)	Std. Dev.	V	X
10 - 11 AM	7.3	1.5	0.2	0.6
11 - 12	11.7	2.0	0.2	0.9
12 - 1	21.1	3.2	0.1	1.7
1 - 2	19.0	3.3	0.2	1.5
2 - 3	12.7	1.1	0.1	1.0
3 - 4	9.7	1.7	0.2	0.8
4 - 5	9.4	1.4	0.1	0.8
5 - 6 PM	9.1	2.4	0.3	0.7
	100.0			

FIGURE VII-3

Temporal Trip Volumes
Summary Data
Department Stores

X = Multiple of Average Hourly Volume

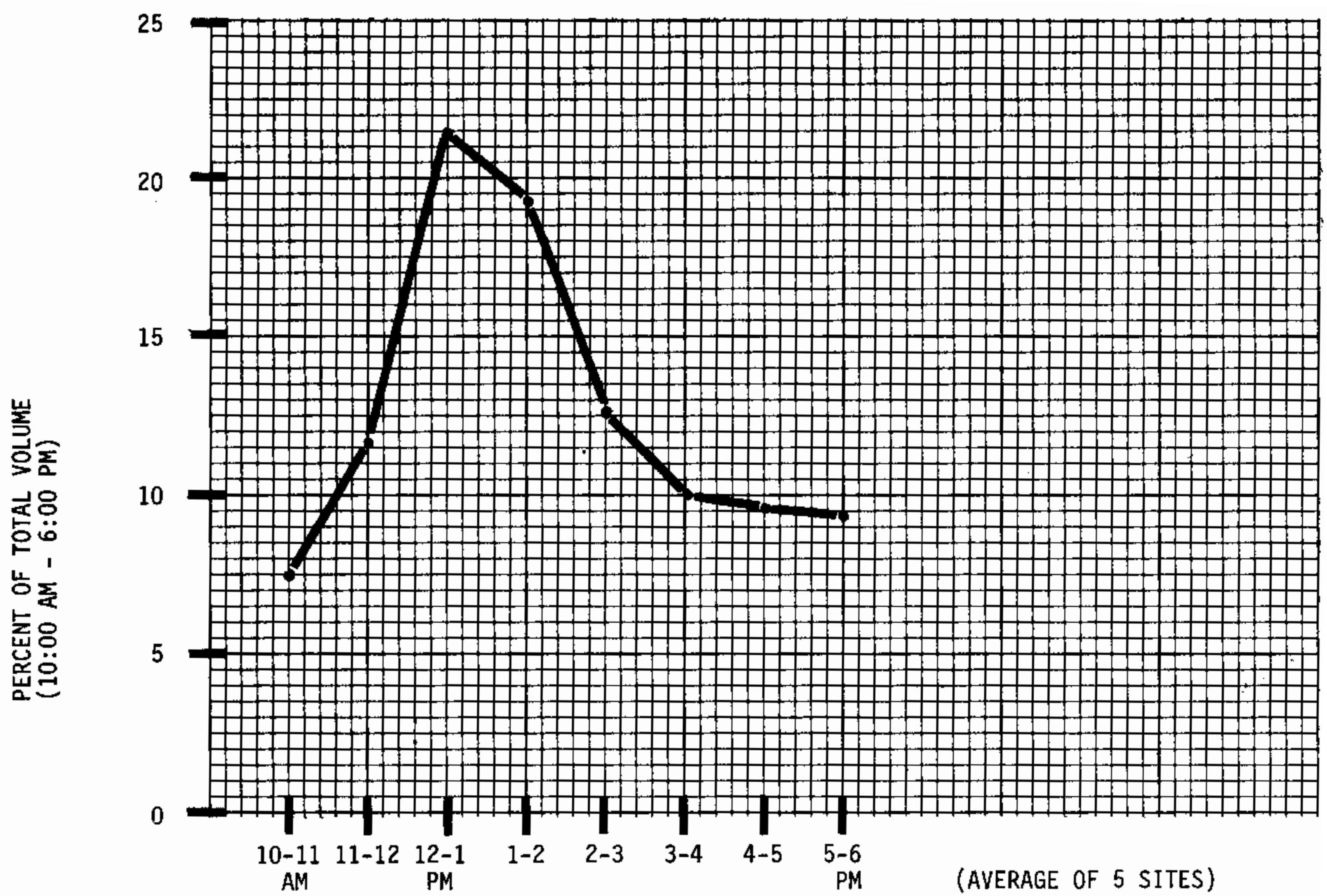


FIGURE VII-4

Temporal Trip Volumes Department Stores

2. Specialty Retailing

For the reason of compatibility similar to those discussed in the section above, only generation during the period 10:00 AM to 5:00 PM was considered.

The summary data for specialty retailing are tabulated and represented graphically in Figures VII-5 and VII-6.

The specialty stores in the sample have a noon hour peak equal to 1.8 times the average hourly volume. The peak hour percentage volumes vary widely depending to some extent on location; for example, specialty stores located near concentrations of offices had greater peaks than those more isolated from offices. Hence, the peak noon hour volumes in the sample ranged from about 1.3 to 3.2 times the average hourly volumes.

The specialty stores data, as might be anticipated, exhibited a substantial variation. This can be varified by examining the coefficient of variation, V, given on Figure VII-5. Examination of the detail data indicates that some of this variation can be explained by locational and land use (Type of Store) factors. However, since a wide range of specialty store types exists and the total impact of these stores is not dominant, no further analysis of the data was accomplished.

Time Period	Specialty Stores			
	Mean (%)	Std. Dev.	V	X
10 - 11 AM	7.4	4.0	0.5	0.5
11 - 12	13.1	5.0	0.4	0.9
12 - 1 PM	25.5	11.8	0.5	1.8
1 - 2	18.3	8.1	0.4	1.3
2 - 3	14.6	5.3	0.4	1.0
3 - 4	11.6	3.7	0.3	0.8
4 - 5 PM	9.9	5.6	0.6	0.7

FIGURE VII-5

Temporal Trip Volumes

Summary Data

Specialty Stores

X = Multiple of Average Hourly Volumes

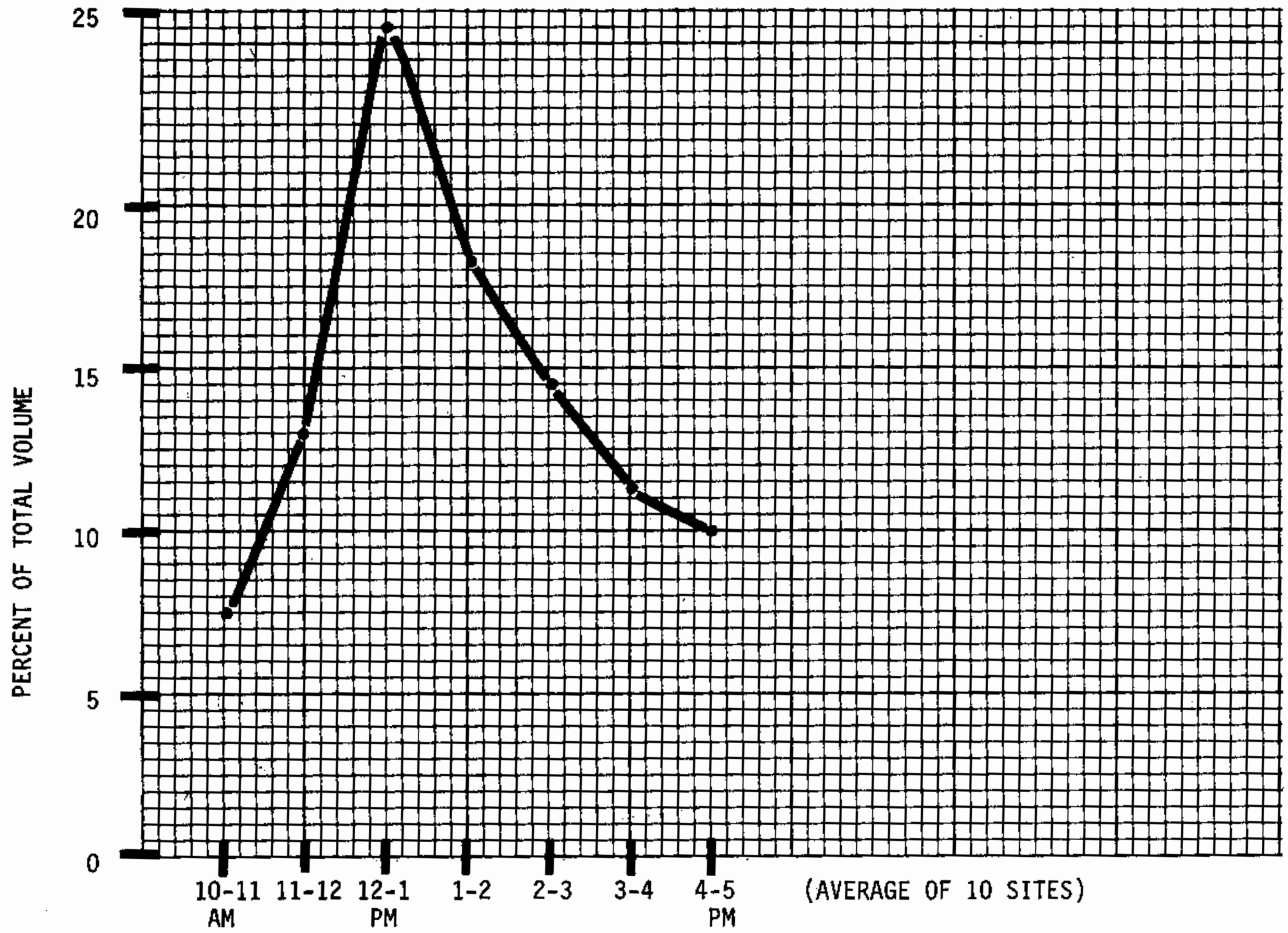


FIGURE VII-6

Temporal Trip Volumes Specialty Stores

The user of these data is advised to recognize the variable nature of the measures, and to adjust the results reported here to suit site-specific conditions.

3. Retail Streets

The temporal distribution of person trips on typical retail streets is of particular interest because it reflects the synthesis of the diversity to retail land uses usually found in urban areas. Data from seven typical retail streets is summarized in Figures VII-7 and VII-8.

The retail street data associated with the sample sites leads to the following findings:

- Trip volumes are fairly constant between 12 noon and 6:00 PM with hourly averages of about 10-15 percent of the 12-hour totals;

- The volume between 12 noon and 6:00 PM accounts for about 70% of the daily (12-hour) total;

- Some moderate peaking occurs curing the noon-hour period, due probably to lunch hour employee shopping, with a magnitude about 1.6 times the average hourly volume; and

- The sample data are reasonably stable, with the period between 1:00 PM and 3:00 PM being most suitable for calibration of trip volumes.

Time Period	Retail Streets			
	Mean (%)	Std. Dev.	V	X
7 - 8 AM	1.9	0.8	0.4	0.2
8 - 9	4.1	2.3	0.5	0.5
9 - 10	4.2	1.5	0.4	0.5
10 - 11	4.8	1.1	0.2	0.6
11 - 12	8.0	1.6	0.2	1.0
12 - 1 PM	13.4	2.7	0.2	1.6
1 - 2	13.6	1.7	0.1	1.6
2 - 3	10.8	1.3	0.1	1.3
3 - 4	10.5	1.6	0.2	1.3
4 - 5	11.7	3.0	0.3	1.4
5 - 6	11.2	2.4	0.2	1.3
6 - 7 PM	5.8	1.6	0.3	0.7
	100.0%			

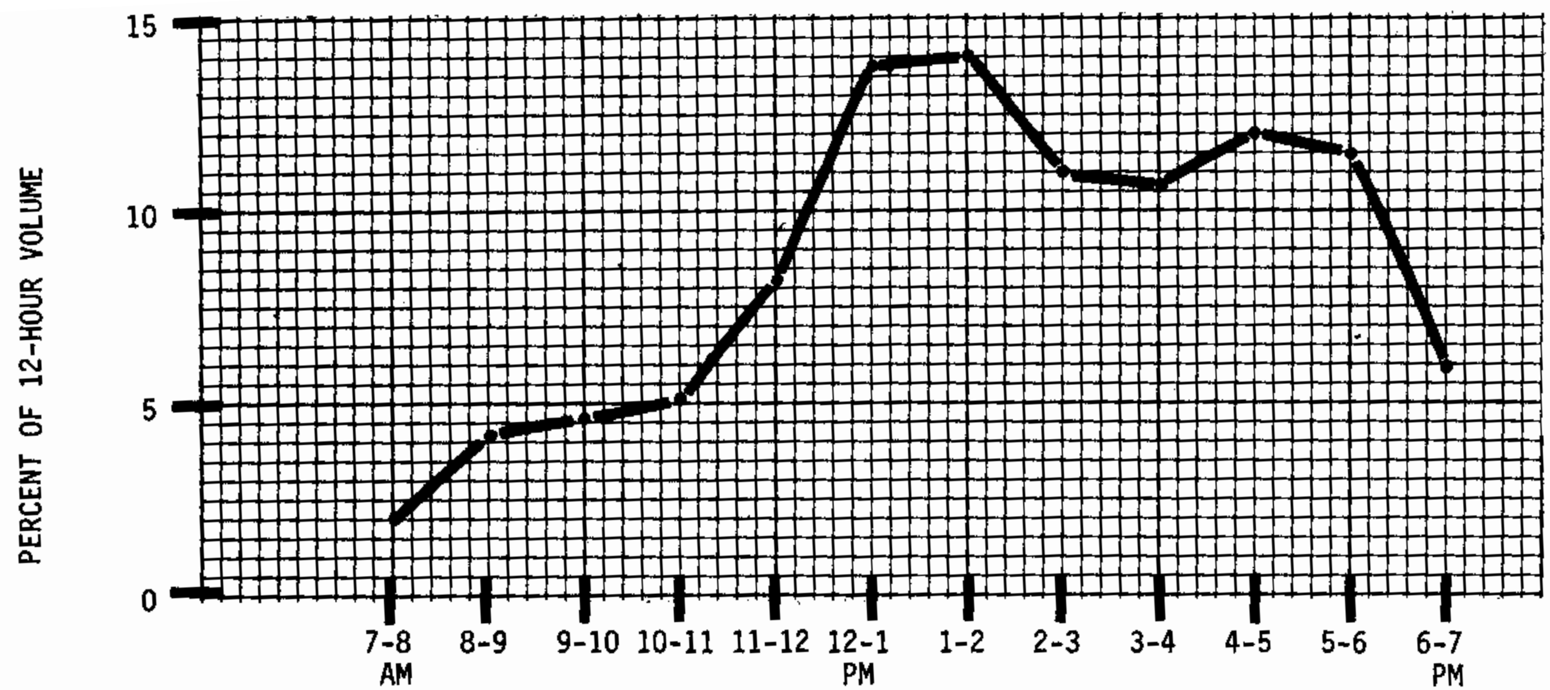
FIGURE VII-7

Temporal Trip Volumes

Summary Data

Retail Streets

X = Multiple of Average Hourly Volumes



(AVERAGE OF 7 SITES)

FIGURE VII-8

Temporal Trip Volumes Retail Streets

D. Mixed Retail and Office Streets

Temporal trip data for three typical mixed-use streets are summarized in Figures VII-9 and VII-10.

A midday peak occurs between 12 noon and 2:00 PM with a magnitude 1.5 to 1.6 times the average hourly volume. As the coefficient of variation, V, indicates the period between 11:00 AM and 2:00 PM is best suited for calibration of trip volume measures.

The temporal distributions for the three street types are compared on Figure VII-11. Careful examination of the figure shows that the mixed-use street is, as expected, a combination of the office-only and retail-only street distributions. The peaks of the office distribution are reflected, as is the high afternoon volumes associated with retail streets.

Time Period	Mixed Retail and Office Streets			
	Mean (%)	Std. Dev.	V	X
7 - 8 AM	4.1	1.8	0.4	0.5
8 - 9	7.2	3.8	0.5	0.9
9 - 10	5.4	0.7	0.1	0.6
10 - 11	6.2	1.4	0.2	0.7
11 - 12	8.8	1.0	0.1	1.1
12 - 1 PM	13.1	1.2	0.1	1.6
1 - 2	12.8	1.1	0.1	1.5
2 - 3	9.0	2.4	0.3	1.1
3 - 4	8.7	2.8	0.3	1.0
4 - 5	9.5	0.9	0.1	1.1
5 - 6	10.2	2.4	0.2	1.2
6 - 7 PM	5.0	0.5	0.1	0.6

FIGURE VII-9

Temporal Trip Volumes
Summary Data
Mixed Retail and Office Streets

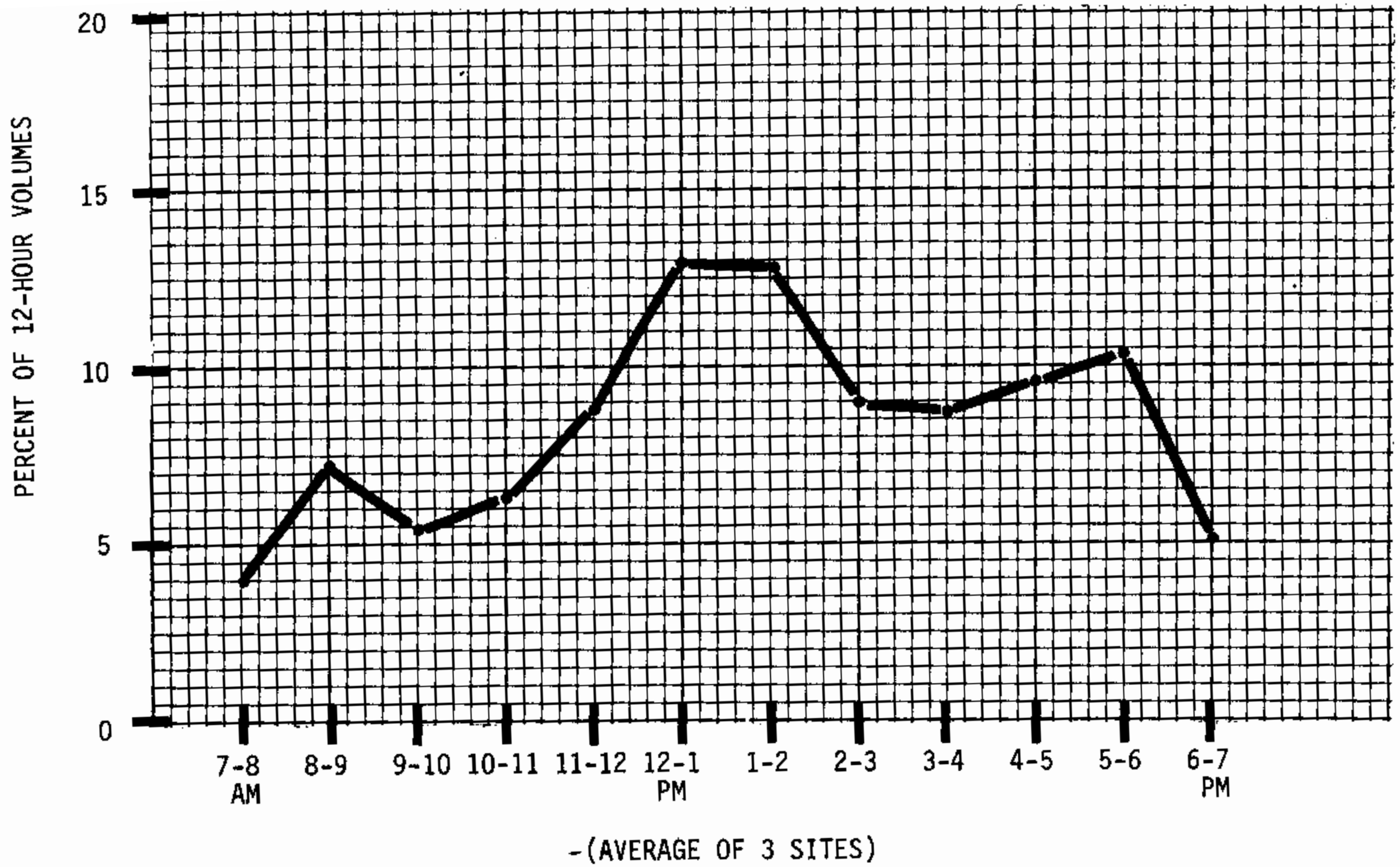


FIGURE VII-10

Temporal Trip Volumes
Mixed Retail And Office Streets

APPENDIX

Trip Generation Data

Site	Data Points	Location	Size (1000)	Average Hourly Person Trips Number	Per 1000
A101	19	Suburb	186.0	332.9	1.8
A102	20	Suburb	170.0	297.5	1.8
A103	21	Suburb	1180.0	1770.0	1.5
A104	22	Suburb	836.0	744.0	0.9
A105	23	Urban	59.0	281.7	4.8
A106	24	Urban	314.0	447.2	1.4
A107	25	Urban	1634.0	1910.4	1.2
A108	26	Urban	1048.0	1139.0	1.1
A109	58	Urban	187.0	263.2	1.4
A110	59	Urban	100.0	403.0	4.0
A111	60	Urban	50.0	97.8	2.0
A112	63	Urban	100.0	59.6	0.6
A113	64	Urban	100.0	140.2	1.4
A114	66	Urban	130.0	246.7	1.9
A115	68	Urban	90.0	232.5	2.6
A116	69	Urban	109.0	180.9	1.7
A117	70	Urban	306.0	655.4	2.1
A118	71	Urban	525.0	746.4	1.4
A119	72	Urban	266.0	336.1	1.3
A120	73	Urban	88.0	139.2	1.6
A121	77	Urban	949.0	856.0	0.9
A122	78	Urban	124.0	261.3	2.1
A123	79	Urban	127.0	160.2	1.3
A124	80	Urban	260.0	275.3	1.1
A125	81	Urban	138.0	175.0	1.3
A126	82	Urban	204.0	576.6	2.8
A127	83	Urban	329.0	877.3	2.7
A128	84	Urban	66.0	206.3	3.1
A129	85	Urban	184.0	630.3	3.4
A130	86	Urban	299.0	553.8	1.9
A131	87	Urban	230.0	296.9	1.3
A132	138	Urban	140.0	367.5	2.6
A133	139	Urban	17.7	128.0	7.2
A134	140	Urban	15.0	219.2	14.6
A135	141	Urban	36.3	528.2	14.6
A136	142	Urban	96.0	104.7	1.1
A137	143	Urban	126.0	208.3	1.7
A138	144	Urban	76.4	109.5	1.4
A139	145	Suburb	50.0	49.8	1.0
A140	146	Suburb	180.0	243.7	1.4
A141	147	Urban	169.0	359.0	2.1
A142	148	Suburb	100.0	94.9	0.9
A143	149	Urban	60.0	135.2	2.3

TABLE 1

Category A Data Base

Site	Data Points	Location	Size (1000)	Average Hourly Person Trips Number	Per 1000
A144	154	Urban	10.0	55.0	5.5
A145	155	Urban	39.0	240.0	6.2
A146	156	Urban	20.0	129.3	6.5
A147	157	Urban	20.0	56.3	2.8
A148	232	Urban	1460.0	1412.9	1.0
A149	234	Urban	852.0	1757.4	2.1
A150	235	Urban	500.0	414.6	0.8
A151	236	Urban	1060.0	1137.9	1.1
A152	238	Urban	1000.0	1493.2	1.5
A153	239	Urban	1660.0	600.7	0.4
A154	240	Urban	863.0	1238.6	1.4
*A155	323	Urban	102.2	167.9	1.6
*A156	324	Urban	311.0	426.0	1.4
*A157	325	Urban	340.7	400.0	1.2

T A B L E 1 (continued)

Category A Data
Base

Class	Site	Data Point	Area (1000 [illegible])	Average Hourly Person Trips Number	Average Hourly Person Trips Per 1000
I	B101	61	600.0	3716.8	6.2
I	B102	62	971.0	2885.5	3.0
I	B103	65	200.0	1113.8	5.6
I	B104	74	18.0	91.8	5.1
I	B105	233	792.0	3416.5	4.3
I	*B106	304	524.0	2977.6	5.7
I	*B107	305	242.0	1278.7	5.3
I	*B108	306	250.0	1381.4	5.5
II	B201	36	7.5	267.5	35.7
II	B202	39	69.6	2233.0	32.1
II	B203	40	14.5	449.5	31.0
II	B204	41	7.5	178.2	23.8
II	B205	42	176.7	3710.7	21.0
II	B206	43	3.4	87.1	25.6
II	B207	67	68.0	1718.8	25.3
II	B208	180	7.8	223.1	28.6
II	B209	182	2.6	61.1	23.5
II	*B210	307	2.2	120.5	54.8
II	*B211	308	2.5	102.6	41.1
II	*B212	309	2.0	50.7	25.3
II	*B213	310	2.9	99.1	34.2
II	*B214	311	0.8	10.9	13.6
II	*B215	312	2.0	6.3	3.1
II	*B216	313	6.5	212.4	32.7
II	*B217	314	0.8	53.8	67.2
II	*B218	315	3.6	101.6	28.2
II	*B219	316	3.8	57.9	15.2
II'	B201	37	7.5	335.0	44.7
II'	B220	38	5.1	288.4	56.6
II'	B206	44	3.4	207.4	61.0
II'	B209	184	2.6	108.6	41.8
III	B301	150	35.8	430.2	12.0
III	B302	151	42.2	354.2	8.4
III	B303	294	83.2	787.5	9.5
III	B304	295	43.6	236.3	5.4
III	B305	296	21.8	528.8	24.3
III'	B301	152	27.1	430.2	15.9
III'	B302	153	35.4	354.2	10.0

TABLE 2

Category B - Data Base

(* = Primary data; sites surveyed by RTKL; Sep/Oct, 1976)

Class	Site	Data Point	Area (1000)	Average Hourly Person Trips Number	Per 1000
IV	B401	291	157.0	1440.0	9.2
IV	B402	292	189.0	843.8	4.5
IV	B403	293	87.0	697.5	8.0
V	B501	158	998.0	3604.1	3.6
V	B502	160	1750.0	3579.8	2.0
V	B503	162	527.7	2340.0	4.4
V	B504	164	1510.2	5857.5	3.9
V	B505	186	1120.0	7560.0	6.8
V	B506	187	609.2	4471.4	7.3
V	B507	188	1050.0	3441.0	3.3
V	B508	189	616.0	2200.8	3.6
V	B509	190	530.0	2308.8	4.4
V	B510	191	667.1	1382.9	2.1
V	B511	192	454.0	3889.0	8.6
V	B512	193	265.0	1930.6	7.3
V	B513	194	850.0	3806.4	4.5
V	B514	243	211.0	2182.5	10.3
V	B515	244	755.0	3813.8	5.1
V	B516	245	811.0	4770.0	5.9
V	B517	246	569.0	3678.8	6.5
V	B518	247	541.0	2216.3	4.1
V	B519	248	560.0	1170.0	2.1
V	B520	249	500.0	2250.0	4.5
V	B521	250	925.0	4094.0	4.4
V	B522	251	175.0	675.0	3.9
V	B523	252	523.0	2598.8	5.0
V	B524	253	379.0	2025.0	5.3
V	B525	254	400.0	4050.0	10.1
V	B526	255	294.0	2025.0	6.9
V	B527	256	500.0	2463.8	4.9
V	B528	257	366.0	2182.5	6.0
V	B529	258	530.0	2958.8	5.6
V	B530	259	341.0	2238.8	6.6
V	B531	260	325.0	1608.8	5.0
V	B532	261	479.0	2362.5	4.9
V	B533	262	183.0	922.5	5.0
V	B534	263	1500.0	7031.3	4.7
V	B535	264	200.0	1822.5	9.1
V	B536	265	1000.0	4691.3	4.7
V	B537	266	120.0	1361.3	11.3
V	B538	267	284.0	562.5	2.0
V	B539	268	241.0	1203.8	5.0

T A B L E 2 (continued)

Category B - Data Base

Class	Site	Data Point	Area (1000)	Average Hourly Person Trips Number	Per 1000
V	B540	269	368.0	675.0	1.8
V	B541	270	300.0	1068.8	3.6
V	B542	271	421.0	1991.3	4.7
V	B543	272	412.0	1361.3	3.3
V	B544	273	270.0	1023.8	3.8
V	B545	274	282.0	1068.8	3.8
V	B546	275	316.0	1383.8	4.4
V	B547	276	460.0	1406.3	3.1
V	B548	277	240.0	377.5	1.4
V	B549	278	166.0	810.0	4.9
V	B550	279	800.0	1631.3	2.0
V	B551	280	280.0	1192.5	4.3
V	B552	281	550.0	2340.0	4.2
V	B553	282	510.0	3206.3	6.3
V	B554	283	395.0	1170.0	3.0
V	B555	284	500.0	1372.5	2.7
V	B556	285	142.0	776.3	5.5
V	B557	286	365.0	1608.8	4.4
V	B558	287	317.0	1428.8	4.5
V	B559	288	725.0	2092.5	2.9
V	B560	289	308.0	675.0	2.2
V	B561	290	1436.0	3150.0	2.2
V'	B501	159	884.0	3604.1	4.1
V'	B502	161	1250.0	3579.8	2.9
V'	B503	163	321.9	2340.0	7.3
V'	B504	165	1144.4	5857.5	5.1
V"	B513	195	850.0	4056.0	4.8

T A B L E 2 (continued)

Category B - Data Base

Class	Data Points	Site	Location	Size 1000	Size Seats	Average Hourly Person Trips Number	Per 1000	Per Seats
I	35	C101	Urban	2.5	---	512.5	205.0	---
I	166/167	C102	Suburb	2.8	82	322.9	115.3	3.9
I	168/169	C103	Urban	2.2	94	357.2	162.4	3.8
I	170/171	C104	Urban	2.8	84	269.3	96.2	3.2
I	228/229	C105	Suburb	3.0	90	264.0	88.0	2.9
I	319/320	*C106	Urban	1.7	85	197.2	116.0	2.3
I	321/322	*C107	Urban	1.3	60	150.6	115.9	2.5
I'	166/167	C102	Suburb	2.8	82	454.2	162.2	5.5
I'	168/169	C103	Urban	2.2	94	432.9	196.8	4.6
I'	170/171	C104	Urban	2.8	84	276.9	98.9	3.3
I'	228/229	C105	Suburb	3.0	90	235.5	78.5	2.6
II	29	C201	Urban	7.2	---	354.2	49.2	---
II	30	C202	Urban	1.0	---	47.8	47.8	---
II	224/225	C203	Suburb	3.8	144	194.3	51.1	1.4
II	226/227	C204	Suburb	4.0	128	214.2	53.6	1.7
II	230/231	C205	Suburb	4.5	165	163.3	36.3	1.0
II'	224/225	C203	Suburb	3.8	144	226.7	59.7	1.6
II'	226/227	C204	Suburb	4.0	128	242.7	60.7	1.9
II'	230/231	C205	Suburb	4.5	165	138.5	30.8	0.8
III	28	C301	Suburb	---	---	---	13.5	---
III	31	C302	Urban	12.0	---	173.0	14.4	---
III	172/173	C303	Suburb	7.5	350	36.4	4.9	0.10
III	174/175	C304	Suburb	10.0	150	61.8	6.2	0.41
III	176/177	C305	Urban	3.4	200	98.7	11.7	0.49
III	178/179	C306	Urban	4.5	161	44.8	10.0	0.28
III	297/298	C307	Urban	---	81	60.0	---	0.74
III	299/300	C308	Urban	---	87	52.3	---	0.60
III	301	C309	Urban	---	178	41.3	---	0.23
III	302/303	C310	Urban	---	90	28.4	---	0.32
III	317/318	**C311	Urban	7.5	220	150.6	20.1	0.68
III'	174/175	C304	Suburb	10.0	150	117.2	11.7	0.78
III'	176/177	C305	Urban	8.4	200	156.8	18.7	0.78
III'	297/298	C307	Urban	---	81	81.8	---	1.01
III'	299/300	C308	Urban	---	87	73.2	---	0.84
III'	302/303	C310	Urban	---	90	44.5	---	0.49

TABLE 3

Category C Data Base

(* = Primary Data; Site Surveyed by RTKL; Oct, 1967)
(**= Primary Data; Site Surveyed by RTKL; Sep, 1976)

Class	Data Points	Site	Size: Units	Size: Residents	24-Hour Person Trips: Number	24-Hour Person Trips: Per Unit	24-Hour Person Trips: Per Resident
I	1/2	E101	8,778	32,411	121,347	13.8	3.7
I	3/4	E102	5,719	21,200	86,837	15.2	4.1
I	5/6	E103	208	984	3,794	18.2	3.9
I	122/123	E104	103	362	2,000	19.4	5.5
I	126/127	E105	137	519	2,656	19.4	5.1
I	128/129	E106	233	818	4,410	18.9	5.4
I	130/131	E107	84	228	1,066	12.7	4.7
I	132/133	E108	250	917	3,765	15.1	4.1
I	196/197	E109	263	1,048	4,040	15.4	3.9
I	198/199	E110	72	235	987	13.7	4.2
I	200/201	E111	225	713	2,733	12.1	3.8
I	202/203	E112	291	1,274	3,171	10.9	2.5
I	204/205	E113	1,000	3,102	14,912	14.9	4.8

T A B L E 4

Category E - Data Base

Single Family Dwellings

Class	Data Points	Site	Location	Size: Units	Size: Residents	24-Hour Person Trips: Number	Per Unit	Per Resident
II	7/8	E201	Suburb	2,508	5,510	26,615	10.6	4.8
II	9/10	E202	Suburb	3,029	6,975	30,956	10.2	4.4
II	11/12	E203	Suburb	2,821	5,074	23,301	8.3	4.6
II	13/14	E204	Urban	288	486	2,189	7.6	4.5
II	16/17	E205	Urban	136	218	1,088	8.0	5.0
II	124/125	E206	Suburb	238	322	1,205	5.1	3.7
II	134/135	E207	Suburb	328	600	2,134	6.5	3.6
II	136/137	E208	Suburb	235	325	1,794	7.6	5.5
II	206/207	E209	Suburb	297	550	2,778	9.4	5.1
II	208/209	E210	Suburb	162	445	2,016	12.4	4.5
II	210/211	E211	Suburb	116	182	1,148	9.9	6.3
II	241/242	E212	Suburb	104	208	650	6.2	3.1

TABLE 4 (continued)

Category E - Data Base

Apartments

Class	Data Points	Site	Location	Size: Occupied Rooms	Size: 1000	Person Trips (See Note): Number	Person Trips: Per Room	Person Trips: Per 1000
III	75	E301	Urban	--	425	4,606	--	10.8
III	212	E302	Suburb	1,858	---	24,920	13.4	--
III	213	E303	Suburb	1,597	---	17,080	10.7	--
III	214	E304	Suburb	31	---	356	11.5	--
III	215	E305	Suburb	64	---	986	15.4	--
III	216	E306	Suburb	15	---	196	13.1	--
III	217	E307	Suburb	280	---	3,578	12.8	--
III	218	E308	Suburb	225	---	4,217	18.7	--
III	219	E309	Suburb	39	---	255	6.5	--
III	220	E310	Suburb	105	---	1,649	15.7	--
III	221	E311	Suburb	154	---	2,304	13.1	--
III	222	E312	Suburb	255	---	2,507	9.8	--
III	223	E313	Suburb	112	---	2,296	20.5	--
III	237	E314	Urban	---	664	12,860	--	19.4

TABLE 4 (continued)

Category E - Data Base

Hotels/Motels

Note: All suburban counts are 24-hour; Site E301 counted 10:00 AM - 6:00 PM, and Site E314 counted 7:00 AM - 6:00 PM.

SUPPLEMENT 3

PROCEDURES FOR FIELD MEASUREMENT OF PEDESTRIAN TRIP GENERATION DATA

Most major cities have conducted counts of pedestrian movement. In general, the counts can be characterized as two types: (1) counts that are oriented to specific centroids such as office buildings or subway stations; and (2) counts that are oriented to specific pathway links such as sidewalks or skyways (i.e., Minneapolis). Unfortunately, the numerous efforts are largely incompatible for the purpose of establishing generalized measures which can then be related to land use, climatic, temporal or other similar variables. Difficulties usually include: (1) non-comparable count durations (for example - fifteen minute counts can be aggregated to obtain hourly counts, but the reverse is not possible); (2) insufficient data regarding the characteristics of the centroid or pathway link negates any attempt to relate volumes to influencing factors; or (3) detailed data is often summarized for presentation, so that the resultant information is useless for research purposes unless the primary source data can be located.

Given that an adequate data base did exist, it would be possible to examine comparable person-trip volumes against various other factors. Hopefully, this research would yield trip generation statistics, with a sufficiently small amount of variability, that could be used in general application given a similar profile of influencing factors.

The following guidelines are suggested as minimum criteria for the collection of pedestrian trip volume data:

- The basic unit of measurement should be the number of trips observed during a fifteen minute period.

- Where applicable, counts should discriminate the directionality of the trips; that is, trips into and out of a given centroid during a fifteen minute period should be recorded separately.

- All available data regarding land use, time and date climatic conditions (temperature, degree of precipitation, etc.), relationship to special activities, and similar information should be recorded as part of the data. Centroids should be characterized in terms of type (see Supplement 2) and size (square feet, floor area ratios-fars, number of employees, restaurant seating, etc.), and accompanied by a narrative description that would provide insight into the nature of its pedestrian generation. Pathway links should be characterized in terms of size, capacity, degree of slope, abutting activity (using detailed centroid data), and other influencing factors such as extent of inactive length, amenities, qualitative assessment of attractiveness, potential security problems, and comfort provision (cover, enclosure, climate control). Observed characteristics of the trip makers and possible trip purposes would also be useful.

- Given constraints on available resources, priority should be given to conducting the counts to encompass peak activity periods; this would include, in order of importance, the noon peak (generally 11:30 A.M. to 1:30 P.M.), the evening peak (4:00 to 6:00 PM), and the morning peak (7:30 to 9:30 A.M.).

- For centroids, care should be taken to account for all portals; this would include garage entrances for centroids, such as office buildings, that have internal parking. Counts should include all car occupants.

SUPPLEMENT 4

THE DEVELOPMENT OF PEAK-DIRECTIONAL FACTORS BASED ON THE TEMPORAL DISTRIBUTION OF PEDESTRIAN TRIPS

1. Introduction

The periods of primary importance to the analysis of pedestrian movement are those associated with peak volumes. In urban areas, these periods usually occur during the A.M. and P.M. commuter rushes, and during the noon hour. In this Supplement, an examination of these peak period characteristics is conducted to support pedestrian movement analysis. In particular, data associated with specific land uses and peak periods is summarized, and a set of factors is developed for adjusting average hourly pedestrian trip volumes to obtain the peak, directional measures required to conduct trip exchange analysis.

In the analysis of trip exchange, the peak trip production and trip attraction volumes of various land use types is required. These figures will be obtained by multiplying the average hourly trip volumes for a given land use, R (see Supplement 2), by a factor, F*, that accounts for the peak activity level and the production/attraction directionality of the movement. Hence,

$$\begin{aligned} P(I) &= \text{Trip Production Volume of Centroid I} \\ &= R(I) \cdot F \quad ; \end{aligned}$$

where R(I) is the average two-way volume per unit of time (usually hourly) for centroid I, and F is the adjustment factor. The factor, F, is a combination of up to three other factors as follows:

$$F = F1 \cdot F2 \cdot F3$$

where F1 = The ratio of peak period two-way volume to average two-way volume over a given time period;

F2 = The percentage of trip out (for trip production measures), of trips in (for trip attraction measures);

F3 = The fraction of an hour represented by the peak period under consideration.

In the following sections, available data are examined to obtain estimates for F for various land uses and peak periods. Since F3 is a constant, the analysis will focus on estimation of F1 and F2.

*Note: In the Procedures manual this F factor is called a PD (peak-directional) factor to avoid confusion with the Friction Factors, referred to as F(I,J).

Site	15 Minute Peak			30 Minute Peak			60 Minute Peak		
	F1	F2	F1 * F2	F1	F2	F1 * F2	F1	F2	F1 * F2
1	1.70	0.73	1.25	1.80	0.68	1.22	1.79	0.57	1.03
2	1.87	0.86	1.61	1.76	0.86	1.51	1.68	0.81	1.37
3	1.94	--	--	1.92	--	--	1.79	--	--
4	--	--	--	2.77	0.70	1.95	2.10	0.66	1.38
5	--	--	--	1.64	0.50	0.81	1.41	0.55	0.78
6	--	--	--	1.60	0.58	0.93	1.79	0.46	0.83
7	--	--	--	1.97	0.52	1.02	1.70	0.51	0.87
8	--	--	--	1.79	0.52	0.94	1.69	0.44	0.74
9	--	--	--	1.39	0.68	0.94	1.50	0.60	0.90
10	--	--	--	1.89	--	--	1.71	--	--
11	--	--	--	1.82	--	--	1.78	--	--
12	--	--	--	1.69	--	--	1.57	--	--
Mean	1.84	0.80	1.43	1.84	0.63	1.17	1.71	0.58	0.99
Std. Dev.	0.12	0.09	0.25	0.33	0.12	0.39	0.17	0.12	0.25

FIGURE 4-1

F Factors

2. Factors for Estimating Noon Office to Retailing Trips

Four trip components will be examined:

- Noon Peak; places of employment; trips out
- Noon Peak; normal retailing; trips in
- Noon Peak; speciality retailing; trips in
- Noon Peak; food-related retailing; trips in

a. Noon Peak, Places of Employment; Trips Out

This component consists mainly of employee lunch trips from offices, and similar places of employment, to both non-food and food-related retail centroids. Applicable data are provided in Figure 4-1.

From the overall data, the 15-minute peak is about 84% greater than the 15-minute average with about 80% of the trips in the out direction; the 30-minute peak is also about 84% greater than the 30 minute average with about 63% of the trips in the out direction; and the corresponding 60-minute values are 71% and 58%.

Based on the data, the following F factors have been developed:

Peak Period	F1	F2	F3	F
15 Minute	1.84	0.80	0.25	0.37
30 Minute	1.84	0.63	0.50	0.58
60 Minute	1.71	0.58	1.00	0.99

b. Noon Peak; Normal Retailing; Trips in

Applicable data are shown in Figure 4-2.

The limited data in Figure 4-2 does not permit reliable estimates of F to be made. However, some very general conclusions can be drawn. The value for F1 probably remains constant throughout most of the noon peak period, at a value of about 1.85. The value for F2 however probably decreases from about 65% (trips in) for the 15-minute peak to approximately 50% as the peak period under consideration is increased. Therefore, the following estimates will be used:

Peak Period	F1	F2	F3	F
15 Minute	1.85	0.65	0.25	0.30
30 Minute	1.85	0.58	0.50	0.54
60 Minute	1.85	0.52	1.00	0.96

	15 Minute Peak			30 Minute Peak			60 Minute Peak		
Site	F1	F2	F1 * F2	F1	F2	F1 * F2	F1	F2	F1 * F2
1	2.98	0.68	2.01	2.98	--	--	2.86	--	--
2	--	--	--	1.61	0.56	0.90	1.69	0.52	0.89
3	--	--	--	1.67	--	--	1.67	--	--
4	--	--	--	1.73	--	--	1.72	--	--
5	--	--	--	1.35	--	--	1.33	--	--
6	--	--	--	1.77	--	--	1.69	--	--
Mean	2.98	0.68	2.01	1.85	0.56	0.90	1.83	0.52	0.89
Std.Dev.	--	--	--	0.57	--	--	0.53	--	--

FIGURE 4-2

F Factors

Noon Peak; Normal Retailing; Trips In

(F2 = % Of Two-Way Trip In)

c. Noon Peak; Speciality Retailing; Trips In

Available data are shown in Figure 4-3. Note that the availability of data is limited; only two-way trip volumes for 30 and 60 minute peaks was isolated.

Site	F1 (Peak Two-Way Factor)	
	30 Minute Peak	60 Minute Peak
1	3.50	3.15
2	1.42	1.40
3	2.92	2.86
4	2.10	1.62
5	5.43	3.67
6	2.16	1.91
7	3.53	3.20
8	1.59	1.45
Mean	2.83	2.41
Std.Dev.	1.32	0.91

FIGURE 4-3

F1 Factors

Noon Peak; Speciality Retailing; Two-Way Trips

Assuming that the 15-minute peak F1 factor is about 3.25, and that the F2 factors approximate those of normal retailing, the following F factors have been developed:

Peak Period	F1	F2	F3	F
15 Minute	3.25	0.65	0.25	0.53
30 Minute	2.83	0.58	0.50	0.82
60 Minute	2.41	0.52	1.00	1.11

d. Noon Peak; Food-Related Retailing; Trips In

Available data are shown in Figure 4-4. The availability of data is very limited.

Making reasonable assumptions based on the limited data, the following F factors were developed:

Peak Period	F1	F2	F3	F
15 Minute	2.80	0.95	0.25	0.67
30 Minute	2.71	0.75	0.50	1.02
60 Minute	2.55	0.60	1.00	1.53

3. Factors for Estimating Noon Retail to Retail Trips

The trip components considered here are those exchanged between normal, speciality and food-related retail centroids. The two-way peak data (F1) from Figures 4-2, 4-3 and 4-4 are used, together with the assumption that the F2 factor, in all cases, is 0.50. This implies that attraction equals production during the periods covered by this analysis. The following F factors, applicable to both trip production, P(I), and trip attraction, A(I), were computed:

Peak Period	F1	F2	F3	F
Noon Peak; Normal Retailing; Two Way Trips				
15 Minute	1.85	0.50	0.25	0.23
30 Minute	1.85	0.50	0.50	0.46
60 Minute	1.85	0.50	1.00	0.93
Noon Peak; Speciality Retailing; Two-Way Trips				
15 Minute	3.25	0.50	0.25	0.41
30 Minute	2.83	0.50	0.50	0.71
60 Minute	2.41	0.50	1.00	1.21
Noon Peak; Food-Related Retailing; Two-Way Trips				
15 Minute	2.80	0.50	0.25	0.35
30 Minute	2.71	0.50	0.50	0.68
60 Minute	2.55	0.50	1.00	1.28

Site	15 Minute Peak			30 Minute Peak			60 Minute Peak		
	F1	F2	F1 * F2	F1	F2	F1 * F2	F1	F2	F1 * F2
1	2.64	0.96	2.53	2.59	--	--	2.28	--	--
2	--	--	--	3.59	--	--	3.47	--	--
3	--	--	--	2.31	--	--	2.30	--	--
4	--	--	--	2.34	--	--	2.15	--	--
Mean	2.64	0.96	2.53	2.71	--	--	2.55	--	--
Std.Dev.	--	--	--	0.60	--	--	0.62	--	--

FIGURE 4-4

F Factors

Noon Peak; Food-Related Retailing; Trips In

4. Evening (P.M.) Peak; Places of Employment; Trips Out

The P.M. component of movement is used for examining commuter trip exchange because it has, in general, a more well-defined peaking characteristic than A.M. movement. Applicable data are shown in Figure 4-5.

Using the 30- and 60-minute peak data for sites 1 - 9 only, and modifying the 15-minute peak data slightly to account for the limited coverage, the following F factors have been developed:

Peak Period	F1	F2	F3	F
15 Minute	3.00	0.93	0.25	0.70
30 Minute	2.52	0.90	0.50	1.13
60 Minute	1.90	0.87	1.00	1.65

5. Evening (P.M.) Peak; Normal Retailing; Trips Out

Applicable data are shown in Figure 4-6.

	15 Minute Peak			30 Minute Peak			60 Minute Peak		
Site	F1	F2	F1 * F2	F1	F2	F1 * F2	F1	F2	F1 * F2
1	2.64	0.83	2.18	2.22	0.83	1.85	2.11	0.84	1.77
2	3.55	0.99	3.50	2.87	0.97	2.78	2.07	0.96	1.98
3	--	--	--	1.42	0.93	0.33	0.94	0.92	0.86
4	--	--	--	1.47	0.87	1.27	1.08	0.79	0.85
5	--	--	--	1.88	0.96	1.81	2.07	0.85	1.76
6	--	--	--	5.29	0.91	4.82	2.92	0.90	2.63
7	--	--	--	3.97	0.95	3.79	2.50	0.94	2.35
8	--	--	--	1.82	0.83	1.51	1.78	0.81	1.45
9	--	--	--	1.69	0.86	1.45	1.69	0.79	1.34
10	--	--	--	1.41	--	--	1.18	--	--
11	--	--	--	1.90	--	--	1.51	--	--
12	--	--	--	1.28	--	--	1.19	--	--
Mean	3.10	0.91	2.84	2.27	0.90	2.29	1.75	0.87	1.67
Std.Dev.	0.64	0.11	0.93	1.22	0.06	1.25	0.61	0.07	0.61

FIGURE 4-5

F Factors

Evening (P.M.) Peak; Places of Employment; Trips Out

Site	30 Minute Peak F1	30 Minute Peak F2	30 Minute Peak F1 * F2	60 Minute Peak F1	60 Minute Peak F2	60 Minute Peak F1 * F2
1	0.74	0.57	0.42	0.76	0.51	0.39
2	0.89	--	--	0.84	--	--
3	0.85	--	--	0.84	--	--
4	0.92	--	--	0.92	--	--
Mean	0.85	0.57	0.42	0.84	0.51	0.39
Std.Dev.	0.08	--	--	0.07	--	--

FIGURE 4-6

F FACTORS

Evening (P.M.) Peak; Normal Retailing; Trips Out

Although the data are limited, it appears that the peaks are constant about 85% of the average for corresponding periods, and that trips out may be slightly greater than 50%. Based on these assumptions, the following factors are proposed:

Peak Period	F1	F2	F3	F
15 Minute	0.85	0.60	0.25	0.13
30 Minute	0.85	0.55	0.50	0.23
60 Minute	0.85	0.52	1.00	0.44

6. Evening (P.M.) Peak; Speciality Retailing; Trips Out

Applicable data are shown in Figure 4-7. Only two-way data for 30- and 60-minute peak periods are available.

Site	F1 (Two-Way Trips) 30 Minute Peak	60 Minute Peak
1	0.50	0.44
2	1.68	1.56
3	0.91	0.73
4	1.11	0.87
5	1.84	1.19
6	1.28	0.96
7	0.83	0.82
8	1.01	1.01
9	0.51	0.36
10	0.86	0.61
Mean	1.05	0.86
Std.Dev.	0.44	0.36

FIGURE 4-7

F1 FACTORS

Evening (P.M.) Peak; Speciality Retailing; Trips Out

Using the limited data, together with the assumption that F1 for the 15 minute peak equals 1.25 and that F2 is a constant 0.50 for all peak periods (this is based on the notion that visits to speciality retail stores are relatively short), the following F factors have been developed:

Peak Period	F1	F2	F3	F
15 Minute	1.25	0.50	0.25	0.16
30 Minute	1.05	0.50	0.50	0.26
60 Minute	0.86	0.50	1.00	0.43

SUPPLEMENT 5

NETWORK REPRESENTATION AND CALCULATION OF PEDESTRIAN DELAYS FOR SIGNALIZED INTERSECTIONS AND UNCONTROLLED CROSSINGS

5.1 Network Representation

The representation of pedestrian network nodes and links at signalized intersections requires special attention. The simple case, consisting of four nodes and six links, is shown in Figure 5-1. A more general case, required for computer processing of the networks, is discussed later in this appendix.

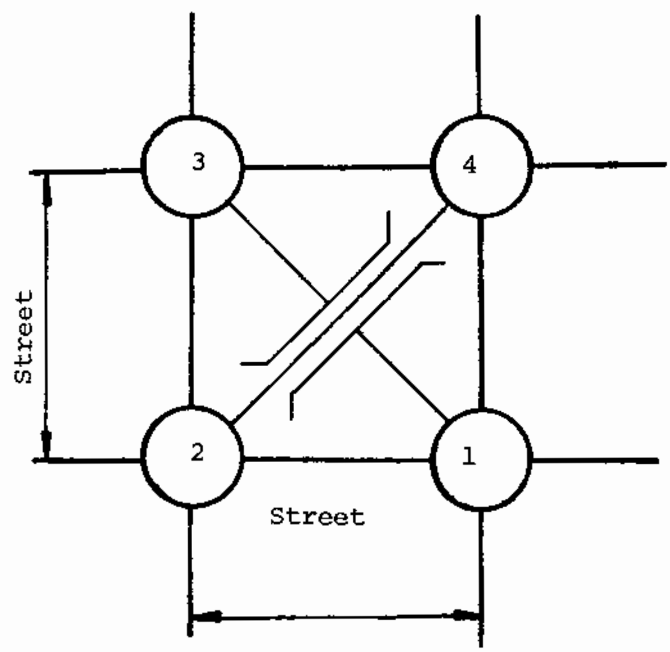


FIGURE 5-1

Network Representation of a Signalized Intersection

(Simple Case)

A right-angle crossing is defined as a traverse of one street using link 1-2, 2-3, 3-4, or 4-1. A diagonal crossing is defined as a crossing of two streets from one corner to a diagonal corner. In terms of pedestrian delay, a diagonal crossing is characteristically different from two independent right-angle crossings. That is, the delay associated with a crossing movement from Node 1 to Node 2 to Node 3 is not the same as the delay associated with the two right-angle crossings - first, from Node 1 to Node 2, then, independently, from Node 2 to Node 3. Hence, the two links 1-3 and 2-4 have been incorporated into the network to represent the diagonal crossing movement.

5.2 Generalized Intersection Representation

For computer processing of networks using available transportation planning programs, there is usually a limitation for links maximum per node, as shown in Figure C-1. This limitation has been exceeded. Therefore, an alternative representation, as shown in Figure C-2, should be used where required.

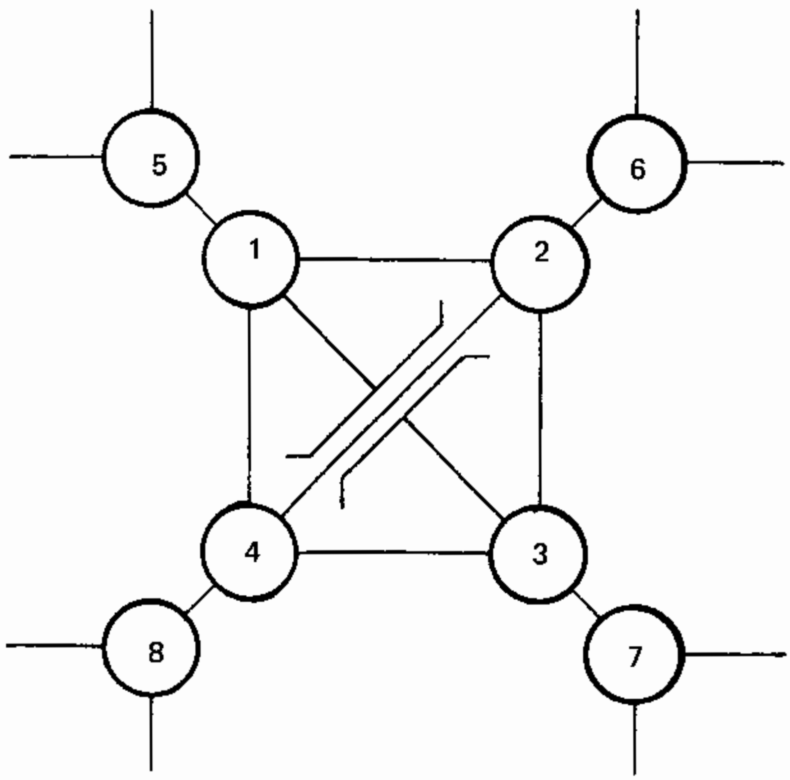


FIGURE 5-2

Network Representation of a Signalized Intersection

(General Case)

The links 1-5, 2-6, 3-7, and 4-8 are zero-length, zero-time paths that act as dummy links in the network. Otherwise, the network processing is unaffected.

The average pedestrian delay, or time equlivalent, associated with right angle crossing of a signalized intersection depends on the approach width--width of the street being crossed; the signal cycle time; and the fraction, R, of "red time" in the direction of pedestrian travel.

5.3 Right-Angle Crossing Delays

Computation of the average delay experienced by pedestrians making right-angle crossings is derived as explained in the following discussion. This delay must be added to the walking time to obtain the total time required to complete the crossing action. From the point of view of the pedestrian, the signal cycle consists of three phases -

$$C = W + FDW + DW$$

where

C = total signal cycle length
W = "walk" phase of cycle in direction of crossing
FDW = flashing "don't walk" phase of cycle
DW = solid "don't walk" phase of cycle

Assuming uniformly distributed random arrivals at the crossing, the probability of a pedestrian arriving during the "walk" phase, where no delay is experienced, is given by the fraction W/c; and the probability of arriving during the "don't walk" phase (flashing or solid), where an average delay of one-half the "don't walk" phase (flashing or solid), where an average delay of one-half the "don't walk" phase is experienced, is given by the fraction (FDW + DW)/C. Therefore, the average delay is -

$$\bar{D} = \text{average delay}$$

$$= \left[(W/C) \quad (\text{zero delay})\right] + \left[(FDW + DW)/C\right] \left[(1/2)\ (FDW + DW)\right]; \quad \text{or}$$

$$\bar{D} = \left[(FDW + DW)/C\right] \quad \left[(1/2) \quad (FDW + DW)\right] \tag{1}$$

The equation for D can be restated in more meaningful terms. Asssuming an average pedestrian walking speed of 264 feet per minute, the minimum FDW phase time required in order to provide the necessary clearance interval for a pedestrian entering the crosswalk during the last second of the "walk" phase is given by

$$\text{FDW (minimum) in minutes} = \text{A (feet)/264 (feet/minute)}$$

where A = approach or street width. A minimum walk time of 7 seconds, as required by the Manual of Uniform Control Devices, was also assumed. Finally, the length of the DW phase is simply the fraction, or percent, of the cycle for which the signal is red in the direction of pedestrian cycle.

This signal-phasing "split" is usually determined by vehicular requirements. As an example, a signal with a 50% red phase on both approaches will be referred to as a 50-50 cycle; similarly, a signal with a 60% red phase in the direction of the pedestrian crossing will be referred to as a 60-40 cycle. Hence,

$$DW = R \cdot C,$$

where

R = fraction, or percent, of signal "red" cycle in the direction of a pedestrian approach.

Making the appropriate substitutions in the equation (1) for average delay (in minutes)

$$\bar{D} = \frac{\left[(A/264) + RC\right]^2}{2C} \qquad (2)$$

where A is expressed in feet and C is expressed in minutes.

Also, due to the minimum requirements on pedestrian "greeN' time and FDW clearance, the minimum cycle, C, in minutes is -

$$C \geq W \text{ (Minimum)} + FDW \text{ (Minium)} + DW$$
$$C \geq (7/60) + (A/264) + RC$$

or

$$\frac{(7/60) + (A/264)}{(1 - R)} \leq C \qquad (3)$$

Equation (2), subject to the constraint given by equation (3), forms the basis for computing pedestrian delays for right-angle crossings.

5.4 Diagonal Crossing Delays

The average delay associated with a diagonal crossing is simploy the delay experienced in making the first crossing plus the delay incurred in making the second crossing. A derivation of the delay is provided in this section.

For the first crossing, delay is computed in a manner similar to that for right angle crossing except that the pedestrian has a choice. For example, consider a crossing from Node 1 to Node 3 (Link 1-3) in Figure 4. At Node 1, the pedestrian has the choice to first traverse Link 1 - 2 or Link 1 - 4 at his convenience. Let Link 1 - 2 be defined as Approach "A", and Link 1 - 4 as Approach "B". Then, the entire signal cycle, from the point of view of the pedestrian, is given by four phases -

$$C = W(A) + FDW(A) + W(B) + FDW(B);$$

where

C = signal cycle length
$W(A)$ = walk phase of Approach "A"
$FDW(A)$ = flashing "don't walk" phase of Approach "A";
$W(B)$ = walk phase of Approach "B"; and
$FDW(B)$ = flashing "don't walk" phase of Approach "B"

For a pedestrian arrival (uniform, random) at Node 1, a delay will be encountered only when there is a FDW phase on either Approach "A" or "B". The average delay at this time will be equal to one-half of the fraction of the cycle associated with the two FDW phases. At other times, the delay is equal to zero, and drops out of the average delay computation, as in the right-angle crossing equation. Hence, for the first crossing, average delay is given by -

$$\bar{D}\text{ (first xing)} = [FDW(A)/C]\ (1/2)\ [FDW(A)] + [FDW(B)/C]\ (1/2)\ [FDW(B)]\ ;\ \text{or}$$

$$\bar{D}\text{ (first xing)} = (1/2C)\left\{[FDW(A)]^2 + [FDW(B)]^2\right\} \qquad (4)$$

For the second approach crossing, the average delay is a function of:

- arrival time at the first crossing, and
- approach crossed during the first crossing.

Four different conditions occur. First, suppose a pedestrian arrives during the FDW(A) phase. In this case, the pedestrian will be delayed before making the fist crossing, and will then begin crossing the "B" approach at the beginning of the W(B) phase. Assuming that the FDW phases are minimum based on 264 feet per minute average walking speed, then the time to cross will be equal to FDW (B), and a wait equivalent to the remainder of the approach "B" green-time will be encountered. Hence, the average delay associated with this first of four conditions is given by -

$$\left[\frac{FDW(A)}{C}\right]\left[W(B) + FDW(B) - FDW(B)\right]$$

or

$$(1/C)\ \ FDW(A)\ \ W(B) \qquad (5)$$

Similarly, an arrival during the FDW(B) phase will result in an average delay of -

$$(1/C)\ \ FDW(B)\ \ W(A) \qquad (6)$$

The third condition arises when the pedestrian arrives at the first crossing during the W(A) phase and encounters zero delay on the first crossing. Then, the delay for the second crossing would range from W(A), for a pedestrian starting the first crossing at the initiation of the W(A) phase, to zero, for a pedestrian completing the first crossing at the termination of the FDW(A) phase (or initiation of the "walk" phase for the second approach crossing). In this case the average delay is given by -

$$(1/C) \quad [W(A)] \quad (1/2) \, [W(A)]$$

or

$$(1/2C) \quad [W(A)]^{2} \tag{7}$$

Similarly, for an arrival at the first crossing during the W(B) phase, the average delay is -

$$(1/2C) \quad W(B)^{2} \tag{8}$$

Hence, the average delay for the diagonal crossing is the delay associated with the first crossing plus the sum of the delays for the four second crossing conditions sum of equations (4) through (8):

$$\bar{D} = (1/2C) \left\{ [FDW(A)]^{2} + [FDW\ (B)]^{2} \right\}$$
$$+ (1/C) \left\{ [FDW(A)] \quad [W(B)] + [FDW(B)] \quad [W(A)] \right\}$$
$$+ (1/2C) \left\{ [W(A)]^{2} + [W(B)]^{2} \right\} \; ; \; \text{or}$$

$$\bar{D} = (1/2C) \left\{ [W(A)] + [FDW(B)]^{2} + [W(B)] + [FDW(A)]^{2} \right\} \tag{9}$$

Following the approach used for right-angle crossing, let -

A(A) - width (feet) of Approach "A";
A(B) - width (feet) of Approach "B";
R(A) - fraction of signal "red" cycle for pedestrian crossing Approach "A"; and
R(B) - fraction of signal "red" cycle for pedestrians crossing Approach "B".

Using these variables -

$[FDW(A)]$ (minimum) in minutes = A(A) (Feet)/264(Feet/Minute)
and
$[FDW(B)]$ (minimum) in minutes = A(B) (Feet)/264(Feet/Minute).

Also, for C expressed in minutes -

$$F(A) = (1/C) \quad W(B) + FDW(B) \quad \text{or}$$
$$W(B) \text{ in minutes } = C \, [R(A)] - \frac{A(B)}{264}$$

and, similarly

$$W(A) \text{ in minutes} = C\left[R(B)\right] - \frac{A(A)}{264}$$

making the appropriate substitutions into equation (9) yields -

$$\bar{D} = (C/2)\left\{\left[R(A)\right]^2 + \left[R(B)\right]^2\right\} + \left\{1/(264^2 \cdot C) \quad \left[A(A) - A(B)\right]^2\right\} + (1/264)\left\{\left[R(A) - R(B)\right]\left[A(A) - A(B)\right]\right\} \qquad (10)$$

also -

C W(A) (Minimum) + FDW(A) (Minimim)
+ W(B) (Minimum) + FDW(B) (Minimum); or

$$C \quad \frac{A(A) + A(B)}{264} + \frac{14}{60} \qquad (11)$$

Equations (10) and (11) form the basis for computing pedestrian delays for diagonal crossings.

If the "A" and "B" approaches are equal, equation (10) is independent of the approach lengths, and can be written -

$$\bar{D} = (C/2)\left\{\left[R(A)\right]^2 + \left[R(B)\right]^2\right\}.$$

Hence, for a given signal split, the delay is a linear function of C, as follows -

50-50 split ... D = 0.25 C
60-40 split ... D = 0.26 C
75-25 split ... D = 0.31 C.

5.5 Delays For Standard Intersection Parameters

The time equivalents of the potential delay have been plotted against the signal cycle time in Figures 5-3, 5-4, 5-6 for 60 foot, 80 foot, and 100 foot approach widths, and 50-50, 60-40 and 75-25 signal cycle splits. These curves were derived using the equations developed above.

To use the curves, choose the curve set assor'ated with the signal cycle split; then enter the graph using the signal cyle length until the appropriate approach width is encountered; the average delay is then read off the left scale. Reasonable accuracy can be obtained by interpolating the curves. However, if more accuracy is desired, or the independent variables are beyond the ranges plotted, refer to the general equations developed in Sections 5-3 and 5-4. The data and equations for right-angle crossing delays are also applicable to both diagonal and right-angle crossings associated with "scramble" or full pedestrian signal phases.

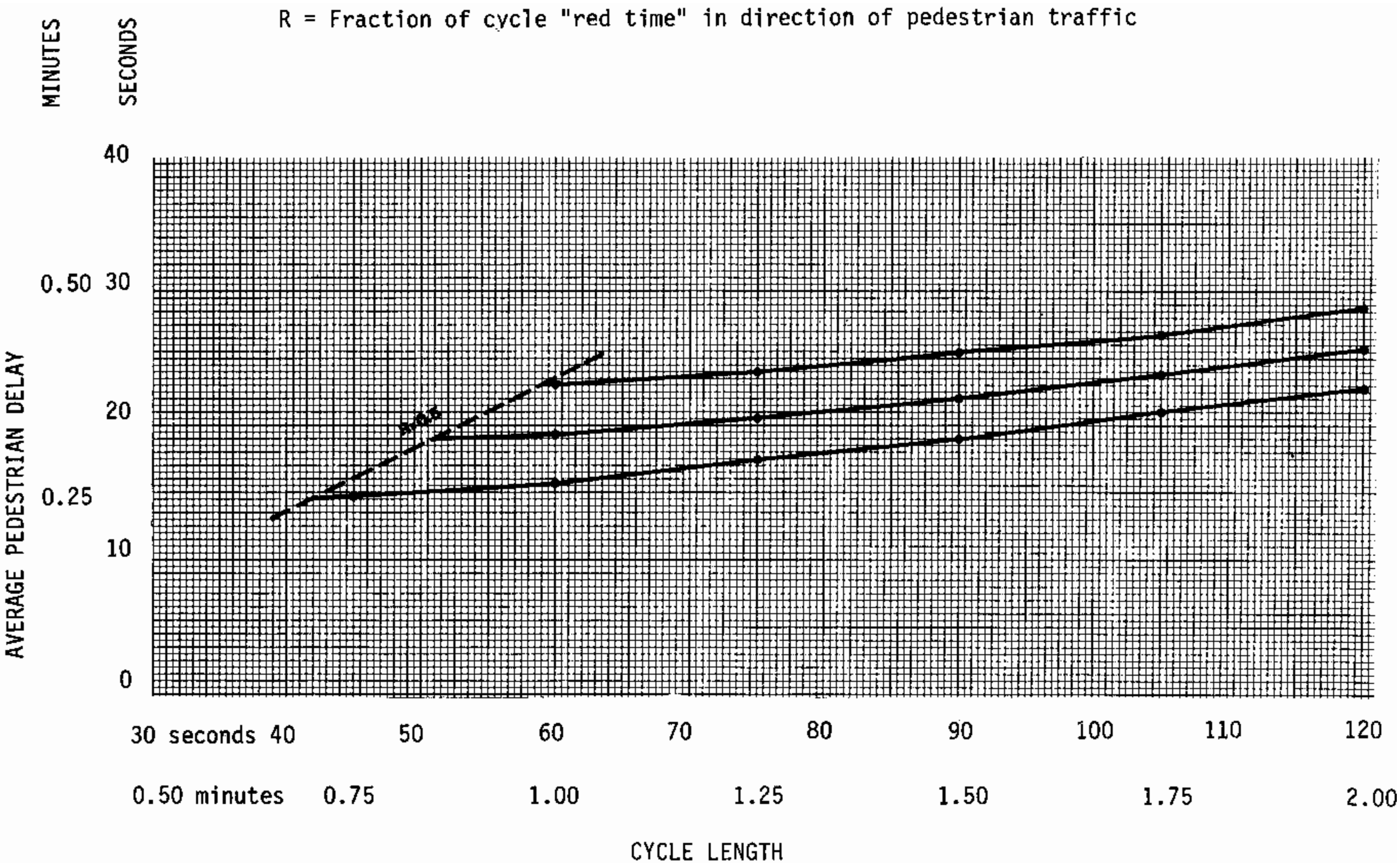


Figure 5-3

Signalized Intersection
Right Angle Crossings
50-50 Cycle

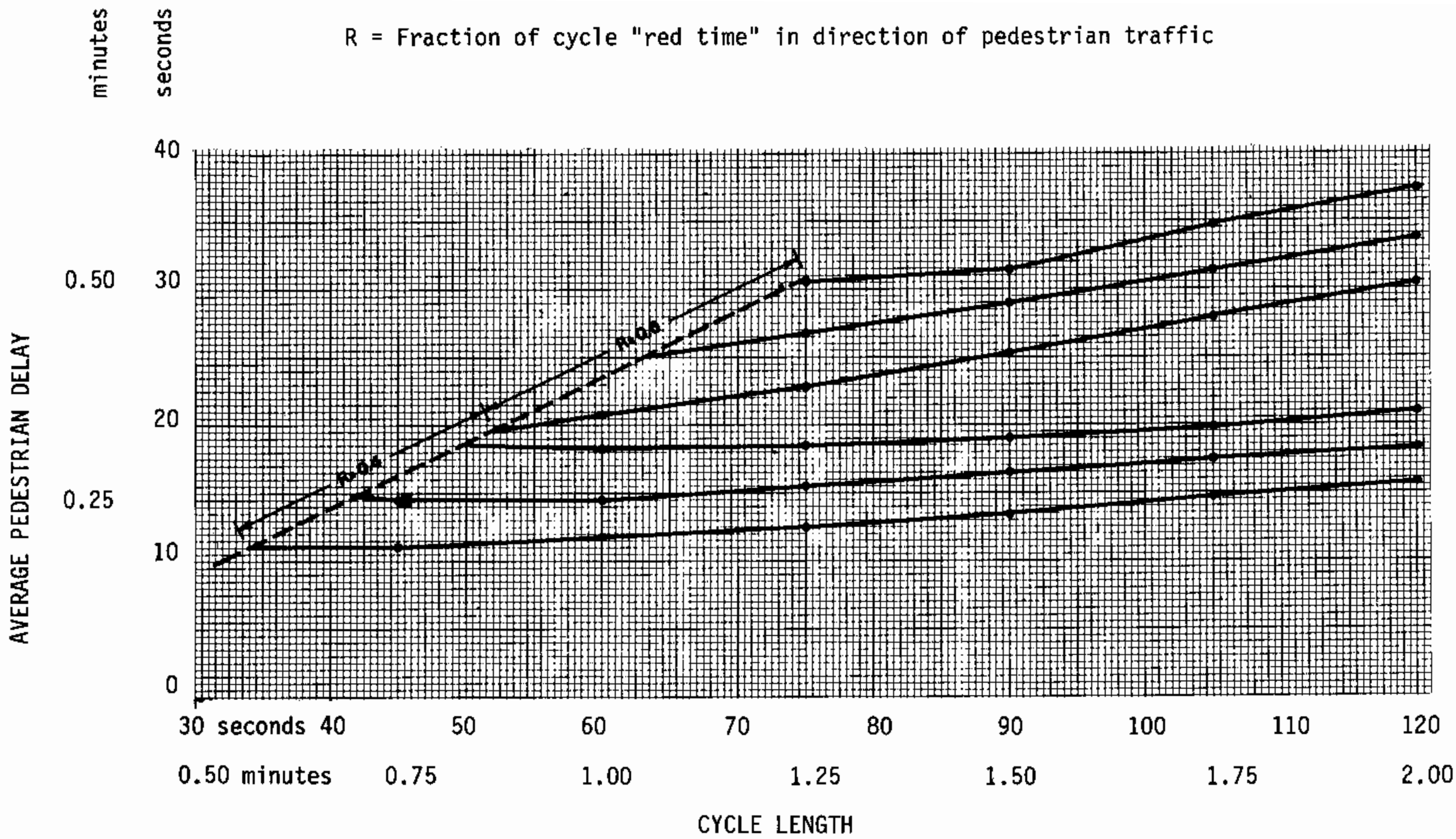


Figure 5-4

Signalized Intersection
Right Angle Crossings
60-40 Cycle

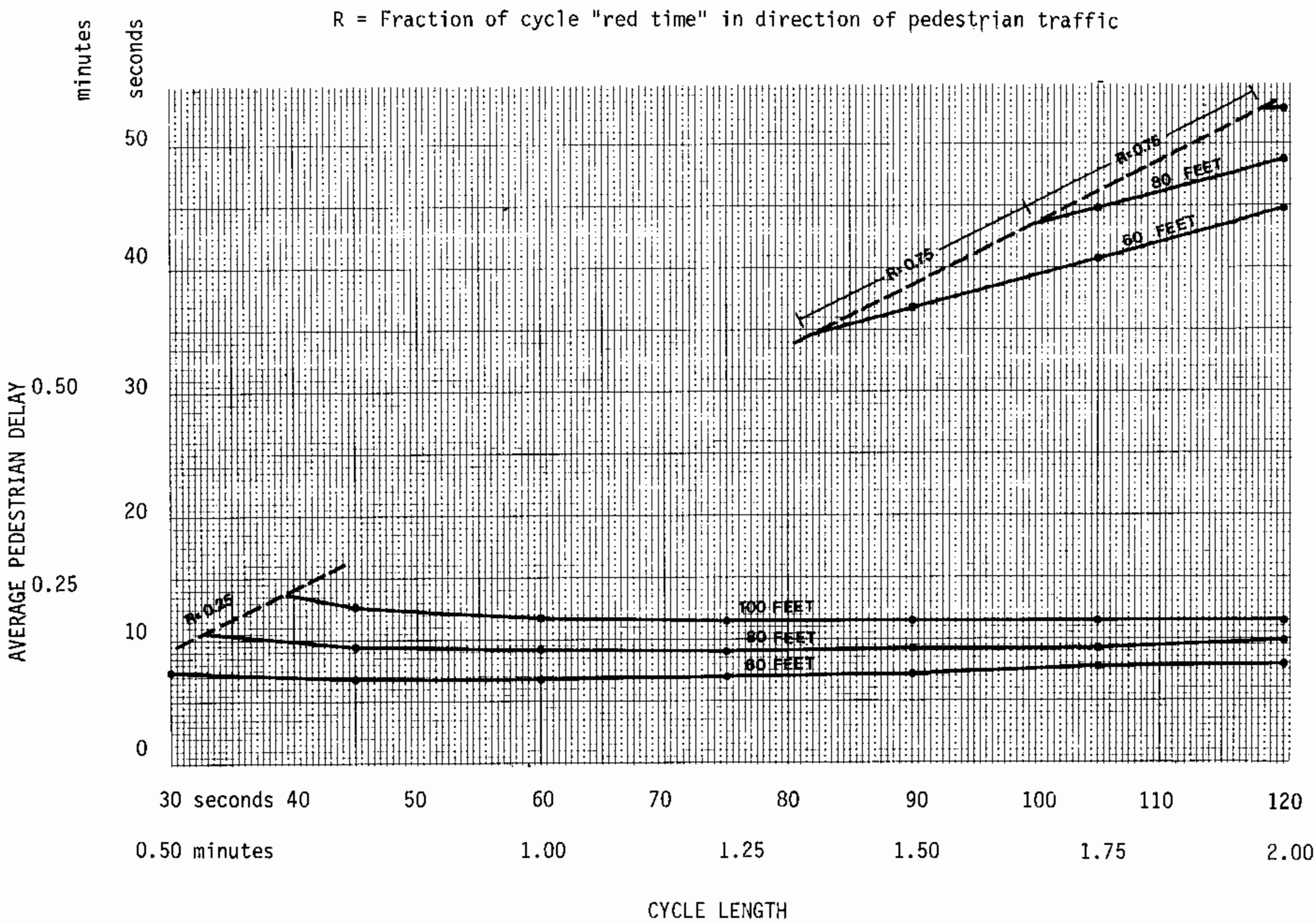


Figure 5-5

Signalized Intersection
Right Angle Crossings
75-25 Cycle

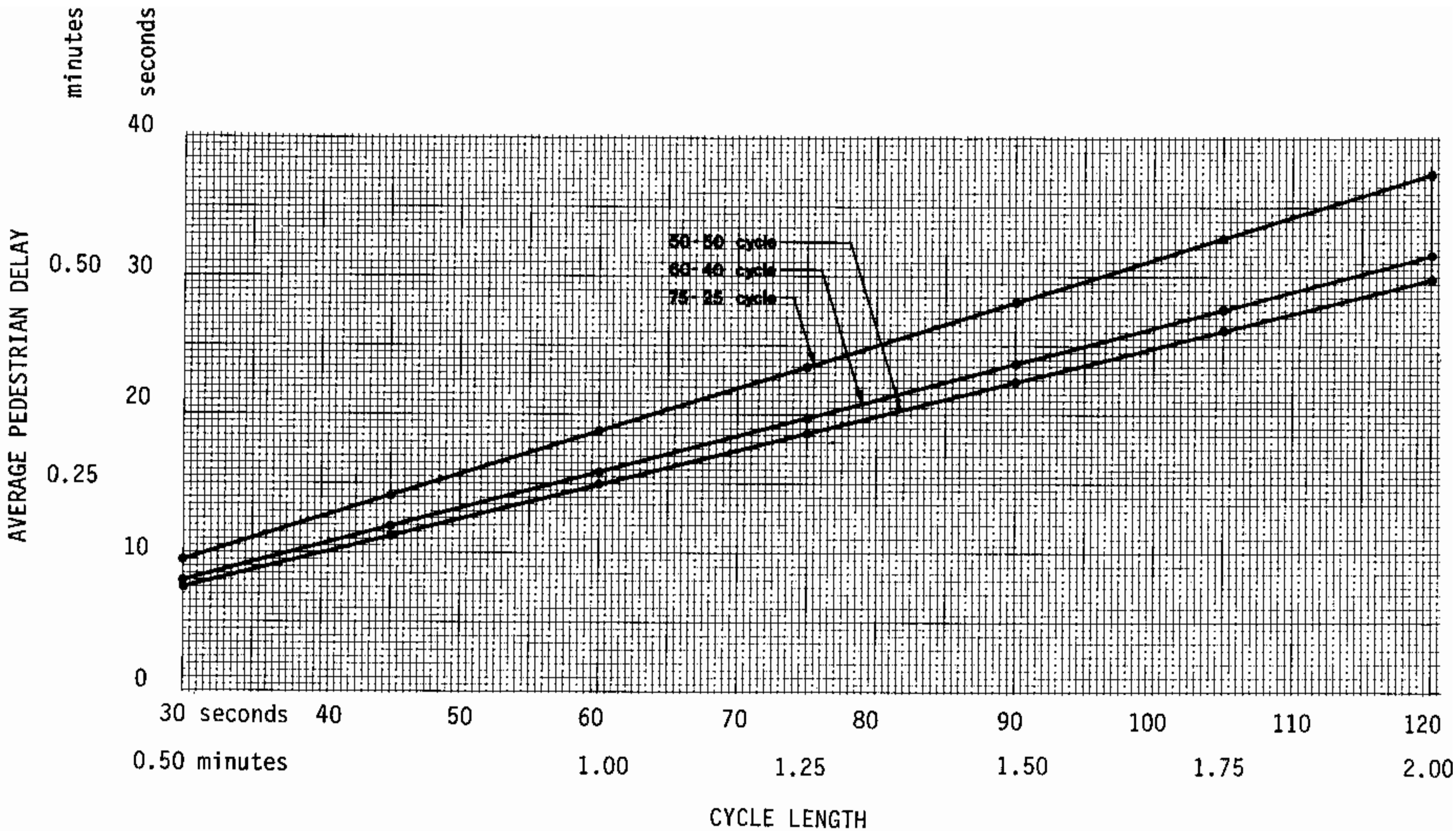


Figure 5-6

Signalized Intersection
Diagonal Crossings
Equal Width Approaches

Average delays, or time equivalents, for diagonal crossings are plotted in Figure 5-7 for equal width approaches. For unequal approach widths, or for other situations not covered by the curves, refer to Sections 5-3 and 5-4.

5.6 Delays to Pedestrians at Uncontrolled Crossings

The estimation of pedestrian delay associated with uncontrolled crossings is made difficult because of the complex interaction of numerous factors, including:

- Street width and type;
- Directionality of traffic flows;
- Vehicular speeds;
- Pedestrian and vehicular volumes;
- Extent of "platooning";
- Pedestrian risk-taking characteristics, etc.

Studies have shown that, even for one-way vehicular traffic, volumes above 1500 vehiculars per hour will cause pedestrian delays on the order of 30 seconds, the points at which pedestrian impatience becomes evident and risk-taking action is apt to occur. For two-way vehicular flows, the same condition will occur at lower volumes.

Data to support estimates of delays at uncontrolled crossings is scant. Existing research tends to focus on crossings outside of urban centers, where traffic flows exhibit more randomized characterisitics, and volumes are generally less. In urban centers, on the other hand, vehicular traffic is usually heavier, but flows are platooned. Furthermore, most crossing points are signalized. Hence, adequate pedestrian crossing gaps usually exist. Pedestrians will also anticipate gaps in vehicular traffic, and will maneuver to take advantage of very short breaks in traffic. Therefore, while the theoretical required gap time might be that period of sufficient length to allow the pedestrian to cross the entire street width at normal walking speed (plus several seconds for perception and reaction time), in reality much less gap time is actually required. Of course, special consideration would have to be given to aged, young or handicapped pedestrians.

Hence, while most existing research would appear to have little applicability, it is reasonable to assume that pedestrian delays at uncontrolled urban crossings should not be greater than those experienced at signalized intersections that control traffic flow on the street to be crossed; since uncontrolled crossings are less constrained, delays at uncontrolled points may be substantially less than at signalized points. While this assumption is somewhat vague, the minimal occurrence of uncontrolled crossings in urban areas reduces the overall impact of variance in individual estimates. A basis for developing estimates is provided in Figure 5-8. The values shown in the table have been developed from existing research, empirical data, and a consideration of factors cited above. Brief observations at existing sites can be used to adjust the table values accordingly.

Vehicles Per Hour (Both Directions)	Street Width (Feet) 24'	36'	48'	60'
200	3	3	4	5
400	3	5	8	12
600	5	9	13	21
800	7	13	21	35
1000	9	18	33	63
1200	12	24	52	96

FIGURE 5-8

Average Pedestrian Delays (Seconds)
At Uncontrolled Crossings
In Central Urban Areas

SUPPLEMENT 6

REPORT ON THE EFFECT OF PATHWAY ELEMENTS ON PEDESTRIAN TRIPMAKING -- INCREASED EFFECTIVE TRIP LENGTH AND TIME

A. BACKGROUND

It has been found from previous research that various pathway elements have a direct influence upon pedestrian tripmaking propensities. Such elements include:

1. Degree of vertical displacement
   - Stairs
   - Ramps
   - Escalators
   - Elevators
2. Degree of horizontal displacement
   - Pathway directness -- degree of turning movements, impedences, etc.
3. Delays
   - At traffic intersections
   - Other forms of conflict/capacity, etc.

To date, however, the specific effects of these pathway conditions have not been measured. While previous research points out that the elements included above have a direct impact (both physical and psychological or real and perceived) upon the propensity for trip-making, as well as the utilizaton of pathways (pathway choice), their specific effects have not been addressed.

B. APPROACH

There are two specific aspects of this problem that require measurement. Both the physical as well as the psychological dimensions of impact must be addressed. The initial approach will attempt to deal with the physical impacts of specific pathway elements upon trip-making.

There is associated with any trip a desirable travel time and walking distance, which is within the range of acceptability to the trip-maker. This time and distance is, for the most part, a function of the purpose of the trip and the trip-maker's objective. Both the dimensions of travel time and distance have been found to influence both:

- The probability that the pedestrian will make the walking trip <u>at all</u>, and
- The probability that he will <u>choose</u> a specific pathway over another.

The desirable travel time and walking distance is a function of many trip-making variables. The energy expended an important variable is a function for the most part of the time and the distance of the trip. Energy cost in trip-making is both real and perceived. Real energy cost in trip-making can be physically measured, and its effect upon trip-making can be addressed in terms of effective travel time and distance.

This approach considers the impact of energy expenditure as well as delay (impedance) upon travel time and desirable walking distance (trip length).

The measurement of effective trip length and travel time is a method by which alternative pathway routes and configurations may be evaluated. Energy expenditure factors in trip-making will be considered one of many evaluation tools developed to measure the relative effectiveness between alternative pathway configuration. Utilizing energy expenditure factors, as well as other evaluation components, each pathway alternative can be scored in terms of minimum time path probability.

The hypothesis can be stated as follows:

If a pathway contains sub-elements (such as stairs, intersections, etc.) which require either additional energy expenditure and/or delay, then both the effective travel time and trip length will increase relative to the existence of these elements. The impact of these elements will constitute reduced pathway utilization and trip-making propensities accordingly, as both pathway utilization and trip-making propensities are a function of real and perceived time and distance.

C. PREVIOUS RESEARCH STUDIES - ENERGY EXPENDITURE

An attempt will be made to measure the effect of the most significant of these pathways elements (i.e., stairs, ramps, etc.) upon effective travel time and walking distance.

Many research studies have been conducted on the effects of stairs and ramps upon human energy expenditure.

The following is excerpted from the paper "Human Responses to Stairways, Walkways and Ramps, Some Recent Findings", by J. A. Templer of the Georgia Institute of Technology:

> Energy Expenditure on Stairs, Ramps and Walkways
>
> Examining the energy costs of walking on the level, on ramps, and on stairways offers a quite different perspective from gait analysis and is useful from two points of view. By comparing the energy demand of various activities, we can see how much effort is demanded by each; but we can also see how well the activity suits the human body, because any action that produces an unusual or arrhymthmic response, demands more energy.

The literature on the energy costs of level walking and walking on ramps is fairly extensive and conclusive; this is not the case for stairs. There are especial technical complexities in measuring the metabolic cost of stair use. However, the stair treadmill, used for the gait analysis, provided a useful laboratory instrument which overcame the main difficulties. And this machine was the focus of the metabolic studies carried out at Haverstraw.

The results of the energy measurements are interesting. Man is not particularly well adapted to stairs. When walking on the level or on ramps, man shows a quite remarkable efficiency. For example, at a speed of about 3 miles per hour, man expends less energy in going from place to place than at any other speed.[1]

Man is well developed to travel long distances on foot and to expend very little energy. On ramps, much the same phenomenon exists; from limited observations, it seems that man adjusts his speed to climb ramps at the least energy cost.[2]

But on stairs, again from limited observations, man does not usually climb at the speed which demands the least total energy. To the body, a stair is a physical obstacle, like rocky or marshy ground, which can be negotiated without much difficulty, but without the extraordinary efficiency with which we travel on the level or on ramps.

However, if we compare the energy costs per vertical meter climbed on ramps and stairs, stairs are more efficient than ramps. Essentially the reason for this is that ramps cause us to cover a considerably greater horizontal distance in addition to the vertical. In transportation terminals and places where this horizontal component is useful to the user, then ramps with grades up to about 15% are more economical in total energy cost than using a stair of any geometry and then walking the remaining distance (to match the ramp travel) on the level; and the lower the pitch of the ramp, the more economical it is.

If the space design does not allow us to use ramps, or if the horizontal movement component is of no particular advantage and we must use the stairs, then to conserve the total energy expended, the steeper the stair the better.[3] And even with ramps, if we are only interested in rising vertically, not in the horizontal movement, then the steeper the ramp, the more economical it is in terms of total energy expenditure.[4]

Rates of Energy Expenditure on Walkways, Stairs and Ramps

The total energy expended is not intrinsically an indicator of fatigue. We can climb a steep stair at the speed which demands the least total energy expenditure, and feel far more tired than if we climbed it at a much more usual and slower pace.

Fatique is related to the rate at which we expend energy rather than the total expended. Stair climbing, even at normal speeds, demands a rate of expenditure that is higher than any routine daily activity.

Ramps up to about an 11°20' pitch, on the other hand, at normal speeds, demand a lower rate of energy expenditure than any stair in general use, and are therefore less fatiguing. And, the lower the pitch of the ramp, the smaller the rate of energy expenditure demanded. But as the pitch of the ramp is increased, a point is reached at a gradient greater than about 20% when certain riser/tread combinations become less demanding than ramps.

---

1 Paul J. Corcoran, "Energy Expenditure During Ambulation", in Downey and Darling (eds.), Physiological Basis for Rehabilitation Medicine, Pennsylvania: Saunders, 1972, p. 194.

2 Ian McDonald, Statistical Studies of Recorded Energy Expenditure of Men, Part 2. Expenditure on Walking Related to Weight, Sex, Age, Height, Speed and Gradient." Nutrition Abstracts and Reviews, 31, no 3. July 1961, pp. 739-761.

3 up to 45°, the limit of the measurements.

4 up to 21°50', the limit of the measurements.

Studies conducted by Passmore and Durnin on human energy expenditure* and Morton, M.D.** on human locomotion provided documentation of energy expenditure rates for various activities related to pedestrian trip-making (ie., walking, climbing stairs and ramps, etc.):

---

*Physiological Reviews, Vol. 35, October 1955, No. 4, p. 801-812.

**Human Locomotion and Body Form, 1952, p. 208-212, Baltimore, Willimas and Wilkan Company.

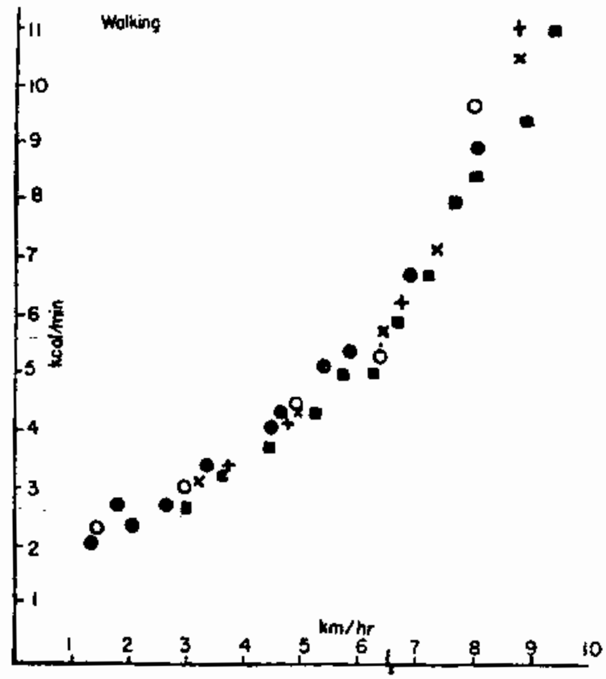


FIGURE 6-1

Energy Expenditure Walking On The Level
At Different Speeds

Figure 6-1 is a composite graph from data recorded of walking at varying speeds in England, Austria, United States, Germany, and Italy. The weights of the subjects were between 60 and 75 kg. For the present purpose so good is the agreement between data from these five laboratories that tabulation of the many other results seems unnecessary.

Over the range 3 to 6.5 km/hr. (approximately 2-4 mph) energy expenditure linearly proportional to speed and the relationship is expressed by the regression equation:

$$C = 0.8V + 0.5$$

where C = energy expenditures in Cal/min and V = speed in km/hr. Figure 6-1 shows that at higher speeds, energy expenditure increases at faster rates.

The effects of weight, age, sex and race on walking on the level at constant speed have been investigated. Measurements were made on 50 persons walking under standard conditions at 4.8 km/hr. (3 mph). Statistical analysis showed that age and race had no significant effect on the metabolic cost of the work. In addition, descending involves only about one-third of the energy used in going upstairs.

Walking on an Incline. Grade walking has also been the subject of many investigations, both on a treadmill and outdoors. Most of the outdoor studies have been done either at high altitudes or using the old Zuntz apparatus which was both heavy and clumsy for the subject. A most comprehensive treadmill study was carried out by Margaria. Figure 6-2 has been drawn from his data and shows the energy cost of walking up gradients of 0, 5, 15 and 25 percent plotted against rate of linear ascent in kilometers per hour for a subject of 70 kg wt. The effect of downhill gradients have not been so systematically studied. Margaria found that going down a slope of 1 in 10 at varying speeds involved an energy expenditure of up to 25 percent less than walking on the level. On very steep declines and especially at slow speeds energy expenditure may be appreciably more than when walking on the level.

That these results have some general applicability is shown by the observations of Keys, Brozek, Henschel, Michelson and Taylor. They found the mean rate of energy expenditure by 16 healthy subjects, average weight 70.6 kg., walking at 5.6 km/hr. up a 10 percent incline to be 8.9 cal/min. This point is marked by a cross in Figure 6-2 and falls almost midway between the lines for the 5 and 15 percent slopes.

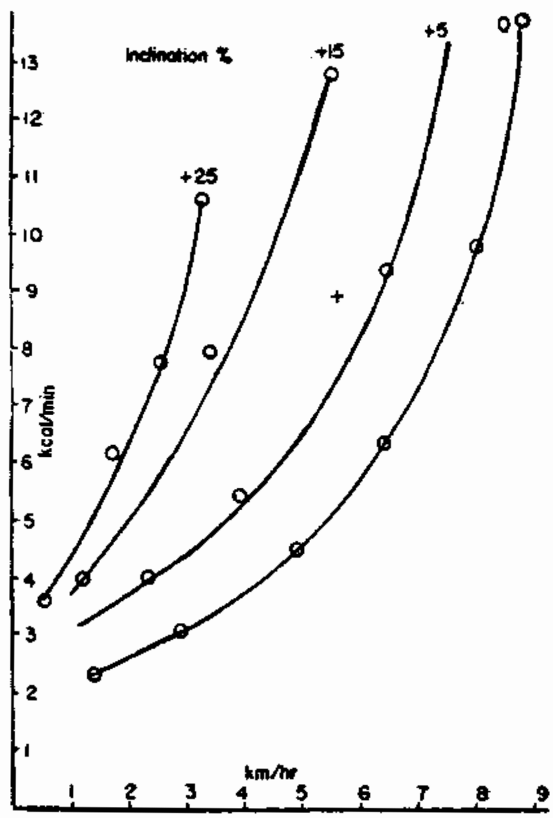


FIGURE 6-2

Energy Expenditure Walking Uphill
At Different Speeds

The data in Figure 6-3 has been developed using the equation cited above and summarizes the information developed by research.

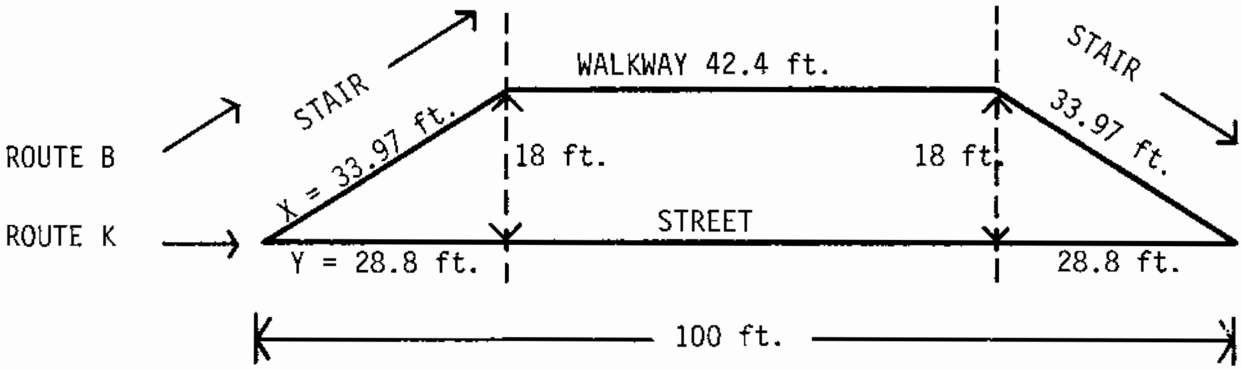
Activity		Average Speed	Energy Expenditure	
			Cal. Per Min.	Cal. Per Ft.
1.	Base Line Walking - Horizontal Surface	265 (FPM) 3 (MPH)	4.34	.016
2.	Stairs *	109 (FPM)		
	(Slope) ↗↙	N/A		
	(Horizontal) ↗	92 (FPM)	6.76	0.073
	↙	128 (FPM)	2.25	0.018
3.	Ramps			
	% Slope			
	0- 5%	265 (FPM)	4.34	0.016
	5- 6%	259	4.89	0.019
	6- 7%	253	5.44	0.022
	7- 8%	247	5.99	0.024
	8- 9%	241	6.54	0.027
	9-10%	235	7.10	0.030

FIGURE 6-3

Effect of Pathway Elements on Walking Speed and Energy Expenditure

D. STAIRWAYS

Example: Impact of Stairs on Total Trip Energy Expenditure



Slope Distance:

$$X = \frac{18}{\sin 32^{\circ}} = 33.97 \text{ ft.}$$

Horizontal Distance:

$$Y = 18 \cot 32^{\circ} = 28.81 \text{ ft.}$$

A - Street Path

Distance	D	=	100 ft.
Speed	S	=	265 FPM
Energy Rate	C	=	4.34 c/m, 0.016 c/f

Total Energy Enpended = 0.016 c/f x 100 ft. = 1.60 cal.

B - Stair/Walkway Path

Up Stairway

Distance	D	= 33.97 ft.
Speed	S	= 92 FPM
Energy Rate	C	= 6.76 c/m, 0.073 c/f.

Total Energy Expended = 0.073 c/f x 33.97 ft. = 2.48 cal.

Walkway

Distance	D	= 42.4 ft.
Speed	S	= 265 FPM
Energy Rate	C	= 4.24 c/m, 0.016 c/f

Total Energy Expended = .016 c/f x 42.4 ft. = .068 cal.

Down Stairway

Distance	D	= 33.97 ft.
Speed	S	= 128 FPM
Energy Rate	C	= 2.25 c/m, 0.018 c/f

Total Energy Expended = .018 c/f x 33.97 ft. = 0.61 cal.

Total Energy Expended

Up	= 2.48 cal.
Walkway	= 0.68 cal.
Down	= 0.61 cal.
	3.77 cal.

Difference

Walkway	= 3.77 cal.
Street	= 1.60 cal.
	2.17 - say 2.2 cal.

Therefore, the total energy expended is over 2 times as great to go up and to come down than to cross the street, or 100 ft. versus 220 ft. effective length. This would be equivalent to walking an additional 120 ft. (or 0.45 min.)

Example: Impact of Stairs on Total Trip Time

There are two components to calculating the net effect of stairs upon effective trip length.

The first is the added expenditure of energy required to negotiate the stair and the conversion of that energy expenditure to effective walking distance.

The second is the delay time in negotiating stairs. That is, since the speeds for ascending and descending stairs are slower than normal walking speeds, the stair has the effect of increasing travel time associated with trip-making. This additional time can then be converted to effective walking distance.

The combination of added energy expenditure and time delay on stairs will yield the net effect upon trip length.

3. Walkway

Speed = 265 FPM

Ft. = 42.4 ft.

$$\text{Time} = \frac{42.4}{265} = 0.16 \text{ min.}$$

4. Stair (Down)

Horiz Speed = 128 FPM
Ft. = 28.8 ft.
Time = $\frac{28.8}{128}$ = 0.23 min.

5. Time Route B, Walkway = 0.31 + 0.16 + 0.23 = 0.70 min.

6. Discounting Horizontal Walk (increasing time) = 0.70 - 0.38 = 0.32 min.

7. Effective Increase in Distance = 0.32 (265) = 84.8 ft.

The effect of the time required to negotiate a stairs is equivalent to adding 85 ft. to the trip length.

The combined effect of energy and time for a stair is equal to:

120 ft.+ 85 ft. = 205 ft. of additional trip length.

Using the bridge configuration of the previous example:

1. Walking (Horizontal Surface)

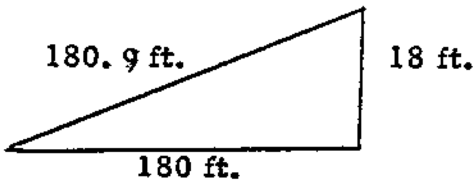
Speed = 265 FPM
Ft. = 100.0 ft.
Time (min.) = $\frac{100.0 \text{ min.}}{265}$ 0.38 min.

2. Walking (Up Stair)

Horiz Speed = 92 FPM
Ft. = 28.8 ft.
Time = $\frac{28.8}{92}$ 0.31 min.

E. RAMPS

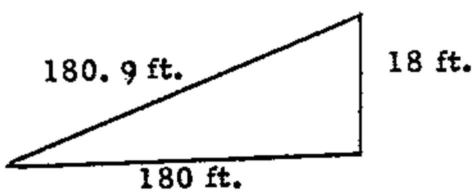
Example: Impact of Ramps on Trip Total Energy Expenditure



10% slope

Horizontal Walk:	Rate:	=	0.016 cal/ft.	
	Dist:	=	180 ft.	
	Energy	=	190 (.016)	= 2.88 Cal.
Ramp:	Rate, 10%:	=	0.030 cal/ft.	
	Dist:	=	180.9 ft.	
	Energy	=	180.9 (.030)	= 5.43 Cal.
Increased Net Energy due to ramp:			5.43 - 2.88	2.55 Cal.
Increased effective Distance:			$\frac{2.55}{0.016}$	159 Ft.

Example: Impact of Ramps on Total Trip Time



10% slope

Horizontal Walk:	Speed	=	265 FPM	
	Distance	=	180 Ft.	
	Time	=	$\frac{180}{265}$	= 0.68 Min.

Ramp: Speed = 235 FPM
Dist. = 180.9 Ft.
Time = $\frac{180.9}{235}$ = 0.77 Min.

Increase Net Effective Distance: (0.09) 265 = 24 Ft.

The combined effect of energy and time for a ramp is equal to:

159 ft. + 24 ft. = 183 ft. of additional trip length

Slope %	Walk Speed (FPM)	Rate/Energy Cal/Ft.	Time Delay* Converted to Distance (Ft.)	** Energy Conv. to Distance	Effect On Trip Length
0 - 5	265	.016	2.6	1.9	5 ft.
5 - 6	259	.019	3	34	37 ft.
6 - 7	253	.022	6	68	74 ft.
7 - 8	247	.024	12	91	103 ft.
8 - 9	241	.027	18	125	143 ft.
9 - 10	235	.030	24	159	183 ft.

* Values given for 18 ft. of vertical change.

**See examples.

FIGURE 6-4

Summary of Impact of Ramps - Conversion to Effective Trip Length

F. ESCALATORS

Example: Escalator Delay Time

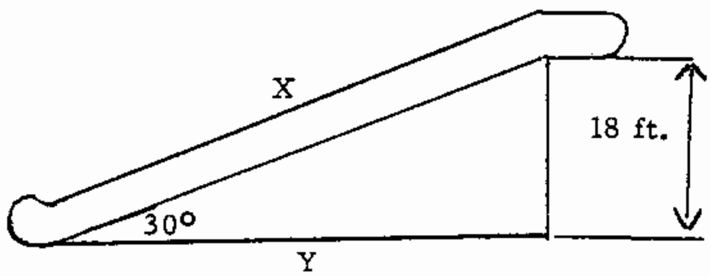
There are two components of delay time relative to escalators.

The first is the time resulting from waiting in the queue.

The second is the time spent traveling on the escalator itself.

Example: Delay Time on Escalator

The second component is calculated as follows and should be added to the queuing time in each case.



1. Escalator speed = 90 FPM

2. Slope Distance $X = \frac{18}{\text{Sin } 30°} = 36$ Ft.

3. Horizontal Distance Y = 18 cot 30° = (18) 1.73205 = 31.2 ft.

4. Time on escalator = $\frac{36}{90}$ = 0.40 minutes

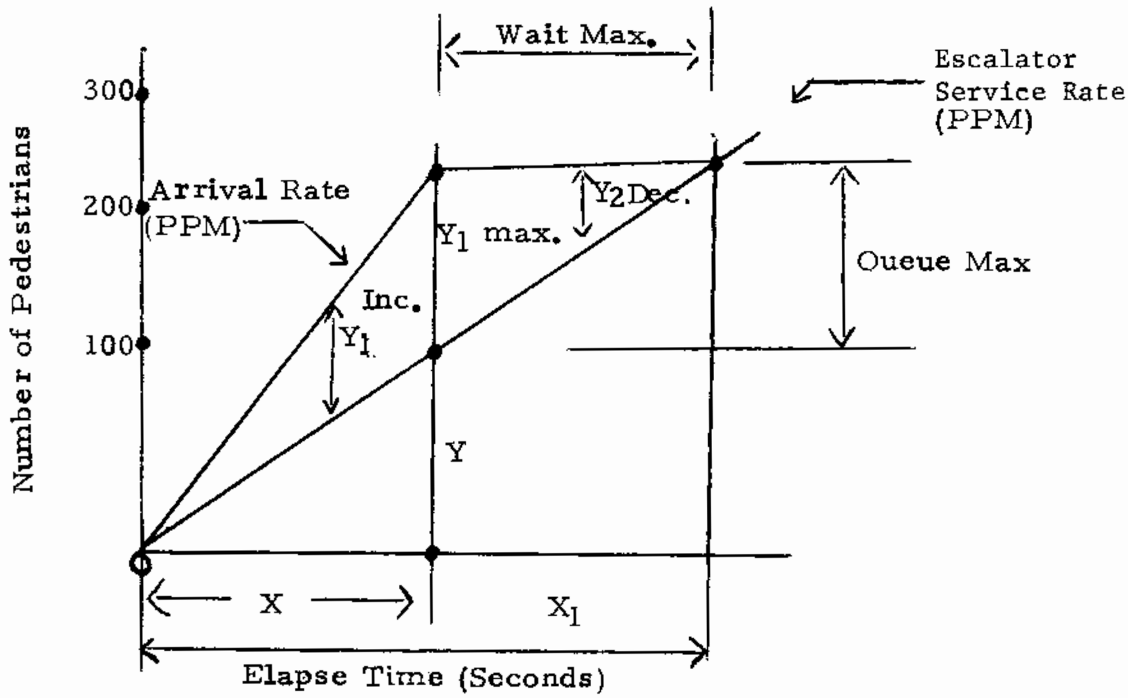
5. Horizontal Time = $\frac{32.2}{265}$ = .12 minutes

6. Discounting Horizontal Walking Time
   .40 min. - .12 = .28 min.

7. Effective Increase in Distance
   .28 min (265 FPM) = 74.2 ft.

Example: Escalator Queue Delay Time

Escalator - Calculation of Delay Time Resulting From Queues



Assumptions:

1. Walking speed = 250 FPM (Ft./Min.)

2. D Max = 150 Ft (Average distance to escalator from points of arrival)

3. Service rate of escalator (S.R.) = 100 PPM

4. Areas available for pedestrian queue = 30 ft. x 50 ft. = 1500 Square Feet

Calculations

1. Pedestrians (P) = $\frac{\text{Area}}{\text{Occupancy*}}$

*Occupancy = The number of square feet per person as defined by various levels of service.

2. Arrival Rate (A.R.) = $\frac{(P)\ Speed}{D\ Max}$ = PPM (Pedestrians/Minute)

3. $Y + Y_1 = \frac{(A.R.)\ (T)}{60}$ where,

A.R. = Arrival Rate in PPM
T. = Elapse time in seconds
60 = Seconds in one minute

4. $Y = \frac{S.R.\ (T.)}{60}$ where

S.R. = Service Rate (PPM)
T. = Elapse time in seconds
60 = Seconds in one minute

5. $Y_1 = \left[\frac{A.R.\ (T.)}{60}\right] - \left[\frac{S.R.\ (T.)}{60}\right]$

for Y_1 (Increasing) at each time interval.

6. X = Time at which maximum queue occurs

$X = \frac{(P)\ (60)}{A.R.}$

7. Y_1 (Max) = The maximum number of pedestrians in the queue

$Y_1 = (P) = \left[\frac{(S.R.)\ (X)}{60}\right]$

8. Y_1 Decreasing

$Y_1 = (P) - \left[\frac{(S.R.)\ (T.)}{60}\right]$

9. X_1 (clearance interval) = $\frac{P\ (60)}{S.R.}$

10. Wait (Max) = $X_1 - X$ (in seconds) where

X_1 = clearance interval, maximum elapse time (in seconds)

Assumptions

1. Walking Speed = 250 FPM

2. D Max (Approach Distance) = 150 Ft.

3. Service Rate (Escalator) = 100 PPM

4. Area = 30 ft. x 50 ft. = 1500 square feet.

5. Level of Service (D) = 10 square feet per pedestrian

Calculations

1. $(P) = \frac{1500}{10} = \underline{150 \text{ Pedestrians}}$

2. $(A.R.) = \frac{150\ (250)}{150} = \underline{250 \text{ PPM}}$

3. For 10 seconds elapse time, T = 10

   $y + Y_1 = \frac{250\ (10)}{60} = \underline{41.67 \text{ Peds.}}$

4. $Y = \frac{100\ (10)}{60} = \underline{16.67 \text{ Peds.}}$

5. $Y_1 = 41.67 - 16.67 = 25.00$ Peds

   e.g., calculate steps (3), (4), (5) for each time interval desired; e.g., 20 seconds, 30 seconds, etc.

6. $X = \frac{150\ (60)}{250} =$ 36 seconds = Time interval at which max. queue occurs

7. $Y_1 \text{ Max} = 150 - \left[\frac{100\ (36)}{60}\right] =$

   $150 - 60 = 90$ Peds.

8. Y_1 for 50 seconds (dec.) $= 150 - \left[\frac{100\ (50)}{60}\right] =$

   $150 - 83.33 = 66.67$ Peds.

9. $X_1 = \frac{150\ (60)}{100} =$ 90 Seconds.

10. Wait (Max.) = 90 - 36 = 54 Seconds

Occupancy SF Area/Person	Level of Service Rating (Fruin)	PPM Peds/Min.	Max. Wait Sec.	Max. Wait Min.	Max. Queue (Peds)
> 35	A	42.8	0.0	0.0	0
25-35	B	60	0.0	0.0	0
15-25	C	100	24.0	0.4	40
10-15	D	150	54.0	0.9	90
	Queue (B)				
5-10	(C)	300	144.0	2.4	240
3- 5	(D)	500	264.0	4.4	440
2- 3	(E)	750	414.0	6.9	690
< 2	(F)	> 750	864.0	14.4	1440

FIGURE 6-5

Summary Table - Delay Time for Escalator Queues

Level of Service	PPM Peds/Min.	Max. Wait Minutes	Wait Converted to Distance (Ft.)	Add Time on Escal.	Total Effect Upon Trip Length
A	42.8	0	0	74	74
B	60	0	0	74	74
C	100	0.4	106	74	180
D	150	0.9	239	74	313
Queue(B) (C)	300	2.4	636	74	710
(D)	500	4.4	1166	74	1240
(E)	750	6.9	1829	74	1903
(F)	> 750	14.4	3816	74	3890

FIGURE 6-6

Summary of Impact of Escalators - Conversion to Effective Trip Length

G. ADDITIONAL TRIP DELAY FACTORS

The total time required for a walking trip must consider, the full range of time delays or penalties which are experienced during the trip.

These penalties include the delay at intersections and variations in walking speed as a result of crowded conditions. The method for calculating the effects on total trip time is based on the following information:

1. One block has an average length of 350 feet.

2. The average walking speed is equal to 265 feet per minute.

3. The average waiting time at intersections is equal to 40 seconds. Typically, a pedestrian would experience a full wait at part the intersections and no wait at others. It can be assumed that a one-half wait at all intersections would be a typical average. This would equal a 20 second time penalty for each intersection. Street crossing time at intersections is figured at 60 feet of ROW and an average speed of 4 feet per second or 15 seconds crossing time.

4. There is not significant effect of crowded conditions on walking speed for densitities more than 20 square feet per pedestrian. The walking speed however is reduced as the density increases and space per pedestrian is reduced.

Occupancy Sq.Ft./Pedestrian	Level of Service	Walking Speed (FPM)	Effect of Crowding Upon Walking Length (FPM)
20+	A	265	0
15	B	225	+ 40
10	C	200	+ 65
7.5	D	175	+ 90
5	E	110	+155

<u>Example: Impact of Intersections and Crowding on Total Trip Time</u>

Using these figures, a trip of four blocks along a moderately crowded walkway (15 square feet per person) would require:

1. 4 times 350 feet = 1400 feet

2. 1400 divided by 225 FPM = 6 minutes, 13 seconds

3. Add 3 intersection delays
   3 times 20 seconds = 60 seconds

4. Add 3 intersection crossings
   3 times 15 seconds = 45 seconds

5. The total trip time is then:

	6 minutes, 13 seconds
	60 seconds
+	45 seconds
	7 minutes, 58 seconds

The effect of the crowding conditions is to increase the travel time by 56 seconds or an equivalent of an additional 247 feet of distance at a normal walking speed.

The effect of the 60 second time delay at the intersections is the equivalent of increasing the trip by 265 feet.

The total effect of these two penalties is to increase the 1400 foot trip to an equivalent of an unimpeded 1900 foot trip.

H. SUMMARY OF IMPACTS OF IMPEDANCE FACTORS

There is associated with any trip a desirable travel time and walking distance, which is within the range of acceptability to the trip-maker. This time and distance is, for the most part, a function of the purpose of the trip and the trip-maker's objective. Both the dimensions of travel time and distance have been found to influence both:

- The probability that the pedestrian will make the walking trip at all, and
- The probability that he will choose a specific pathway over another.

The desirable travel time and walking distance is a function of many trip-making variables. However, for the most part, time and distance are a function of energy expenditure. That is, the degree of energy expended in making a trip. energy cost in trip-making is both real and perceived. Real energy cost in trip-making can be physically measured, and its effect upon trip-making can be addressed in terms of effective travel time and walking distance.

This approach considers the impact of energy expenditure as well as delay (impedence) upon travel time and desirable walking distance (trip length).

The measurement of effective trip length and travel time is a method by which alternative pathway routes and configurations may be evaluated. Energy expenditure factors in trip-making will be considered one of many evaluation tools developed to measure the relative effectiveness between alternative pathway configurations. Utilizing energy expenditure factors as well as other evaluation components, each pathway alternative can be scored in terms of minimum time path probability.

IMPEDANCE FACTOR	SPEED (FT/MIN)	COMPONENTS: A ENERGY EXPENDITURE CAL/MIN	CAL/FT	B TIME/ DELAY (MINUTES)	CONVERSIONS: A+B TOTAL EFFECT UPON TRAVEL TIME (MINUTES)	A+B TOTAL EFFECT UPON TRIP LENGTH (FEET)
A. Walking (Hor.) (No impedance/ base line)	265 FPM	4.34	0.016	0	0	0
B. Stairs** (Slope)*	109FPM					
Up (Conv. to Horz.)	92 FPM	6.76	0.073	0.32 Min	+0.774 Min.	+205 Ft
Down (Conv.to Horz.)	128 FPM	2.25	0.018			
C. Ramps**						
0 - 5%	265 FPM	4.34	0.016	0.01	0.018	+ 5
5 - 6%	259	4.89	.019	0.01	0.140	+ 37
6 - 7%	253	5.44	.022	0.02	0.279	+ 74
7 - 8%	247	5.99	.024	0.05	0.389	+103
8 - 9%	241	6.54	.027	0.07	0.540	+143
9 - 10%	235	7.10	.030	0.09	0.691	+183
D. Escalators	90 FPM					
Level of Service Rating: A	NA	NA	NA	0.0	0.28	+ 74
B	NA	NA	NA	0.0	0.28	+ 74
C	NA	NA	NA	0.4	0.68	+180
D Queue Level (B)	NA	NA	NA	0.9	1.18	+313
(C)	NA	NA	NA	2.4	2.68	+710
(D)	NA	NA	NA	4.4	4.68	+1240
(E)	NA	NA	NA	6.9	7.18	+1903
(F)	NA	NA	NA	14.4	14.62	+3890
E. Traffic Intersect. (20 sec.average wait & 15 sec.crossing time for 60 ft. row)	NA	NA	NA	0.58	0.58	+154
F. Crowding						
Level of Service Rating: A	265	NA	NA	0	0	0
B	225	NA	NA	0.15	0.15	40
C	200	NA	NA	0.25	0.25	65
D	175	NA	NA	0.34	0.34	90
E	110	NA	NA	0.58	0.58	155

FIGURE 6-7

The Effect Of Impedance Factors Upon Travel Time And Trip Length

The hypothesis can be stated as follows:

If a pathway contains sub-elements (such as stairs, intersections, etc.) which require either additional energy expenditure and/or delay, then both the effective travel time and trip length will increase relative to the existence of these elements and that the impact of these elements will constitute reduced pathway utilization and trip-making propensities accordingly, as both pathway utilization and trip-making propensities are a function of real and perceived time and distance.

Figure 6-7: The effect of impedance factors upon travel time and trip length.

Figure 6-7 summarizes each impedence factor and illustrates the total impact of that factor upon travel time and trip length. Each value appearing on the table is relative to an assumed base line which is defined as walking on a horizontal surface at a normal speed of 265 fpm (ft. per minute). The base line for the purpose of comparative analysis is considered to be unimpeded.

The impact upon effective pathway time and distance of each impedence factor, in terms of energy expenditure and time delay, is relative to both the travel time and energy expense of normal walking on a horizontal, unimpeded pathway.

The values given in the table for the total effect upon travel time and trip length are defined as the total number of minutes and feet in addition to that time or distan ce required to make the trip walking horizontally at 265 fpm.

As an example, the values given in the table under "Stairs" indicate an effect upon travel time of .774 minutes and 205 ft. What this means is that, given two pathways, one without a stair (A) and one with a stair (B), the travel time (on the pathway with the stair (B) is .774 minutes greater than (A), and pathway (B) adds 205 feet to the effective trip length as well. In this manner, each impedance adds both a time and effective distance penalty to trip-making upon alternative paths.

The total effect upon travel time and trip length has been computed as follows:

1. Each vertical change component (stairs, ramps, escalators, etc.) is assumed to be for 18 ft. of vertical change. This is usually the minimum distance required (considering clearance and structure) for a second level pathway.

2. The energy expended to ascend and descend a stair or ramp has been calculated utilizing the sources noted in this section.

3. Due to decreased walking speeds relative to going up and down stairs and ramps, comparing these speeds to a normal walking speed of 265 fpm the additional time required to negotiate a vertical change component was calculated. (Component (B), Figure 6-7)

4. The total effect upon travel time and trip length was then calculated by converting both energy and time delay to minutes and feet to arrive at a value for the total impact in terms of time and distance dimensions for trip-making.

5. In the case of escalators, the effect upon both travel time and trip length is entirely a function of time delay resulting from queueing and is a function of the level of service rating in the apron of the escalator. (See Figures 6-12, thru 6-16)

6. In the case of crowding level of service rating results in reduction of walking speeds due to increased density of people. This reduction in speed results in time delay in trip-making which has been converted to effective travel time and increase trip length. Values appearing on Figure 6-7 for crowding impact are given for a 265 lineal ft. of pathway only. The conversion of these values for a specific pathway length are as follows:

<u>Example: Comparison of Effective Trip Length - Alternate Paths</u>

If you have crowding conditions during certain times of day - morning rush, lunch hour, evening rush - for a one-block area on a pathway that is being evaluated relative to effective travel time and trip length, using the <u>minimum time path probability</u> method of evaluation, the calculations would be as follows:

1. Givens:

   a. Block length = 350 ft.
   b. Level of service: based upon field observation of pathway area allotted per pedestrian (Fruin) assume for this example only - level of service "E"
   c. For level of service "E", speed = 110 fpm
      time delay .58 min. for 265 ft. of pathway
      inc. in trip length 153.7 ft.
      (Figure 6-8 and 6-9)

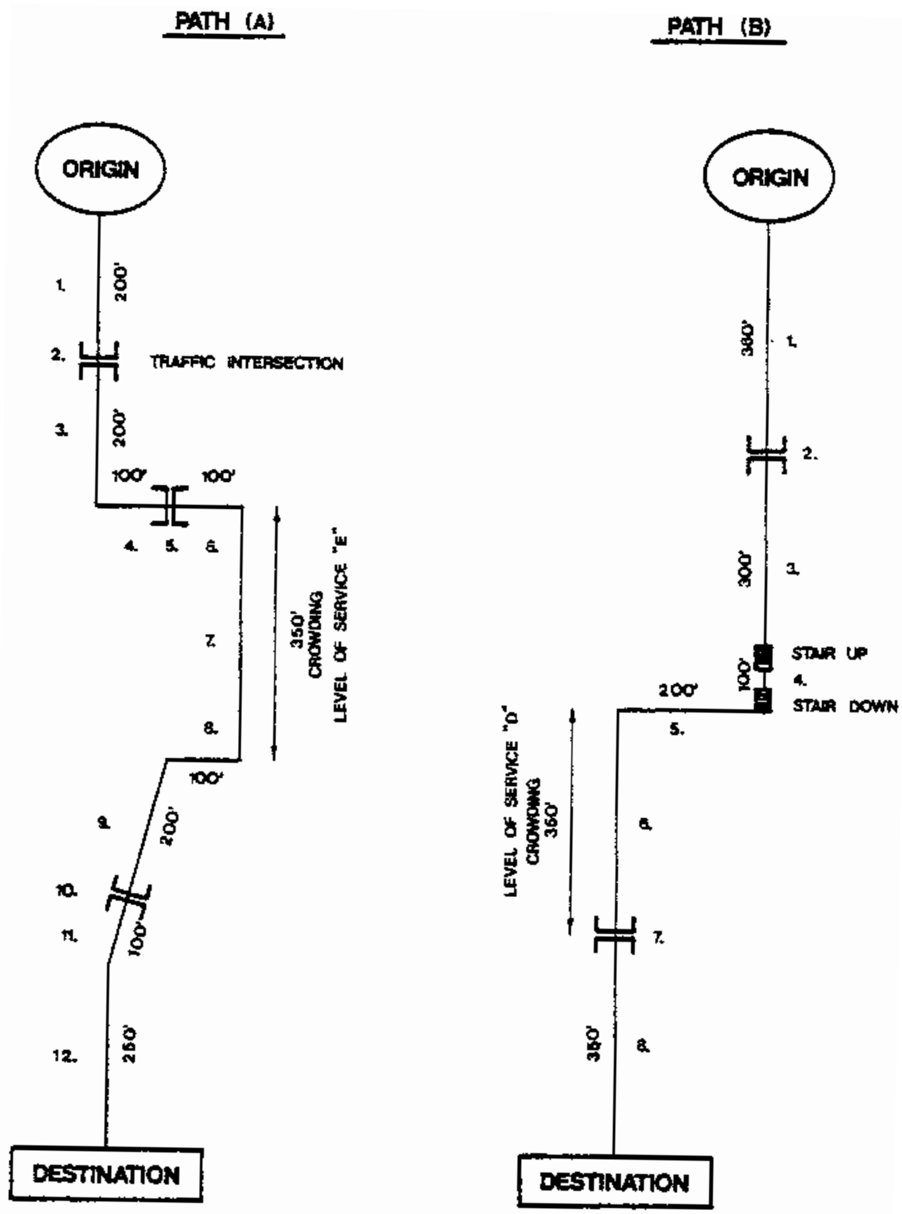


FIGURE 6-8

Example: Impedance Related To Effective Trip Time And Trip Length

(Energy Expenditure And Delay)

Pathway Number	Segment Number	Length of Segment (FT)	Traffic Intersection Time	Traffic Intersection Dist.	Stair T	Stair D	Ramp T	Ramp D	Escalator T	Escalator D	Crowding T	Crowding D	Total Travel Time Effective (Time)	Total Trip Length Effective (Dist)
(A)	1	200	.58	+154									.75	200
	2	60 (ROW)											.58	214
	3	200											.75	200
	4	100											.38	100
	5	60 (ROW)	.58	+154									.58	214
	6	100											.38	100
	7	350									1.86	492.9	1.86	842.9
	8	100											.38	100
	9	200											.75	200
	10	60 (ROW)	.58	+154									.58	214
	11	100											.38	100
	12	250											.94	250
	Total (Unadjusted Length)	1,780 Ft.									Total (Effective)		8.31 (Min)	2,734.9 Ft - 1,780.0 * 954.9 Ft
(B)														
	1	360											1.35	360
	2	60 (ROW)	.58	+154									.58	214
	3	300											1.13	300
Stair (Up/Dn)	4	100			.774	+205							.77	305
	5	200							0.68	180.2			.75	200
Level of Service "D"	6	350											0.68	180.2
	7	60 (ROW)	.58	+154									.58	214
	8	350											1.32	350
	Total (Unadjusted Length)	1,780 Ft									Total (Effective)		7.16 (Min)	2,132.2 Ft - 1,780 Ft * 343.2 Ft

Figure 6-9

Impedance Factor (Impact)

2. Calculations

a. $\frac{\text{Number of lin. ft. of crowding}}{\text{Normal walking speed}}$ = travel time (under normal unimpeded conditions)

or

$\frac{350 \text{ ft.}}{265 \text{ fpm}}$ = 1.32 min., and

b. $\frac{\text{Number of lin. ft. of crowding}}{\text{Level of service walking speed}}$ = actual travel time (due to crowding)

or

$\frac{350 \text{ ft.}}{110 \text{ fpm}}$ = 3.18 min., and

c. Actual travel time - travel time = effective increase in travel time or distance

or

3.18 minutes - 1.32 minutes = <u>1.86</u> minutes of additional travel time

d. For conversion to distance:

Effective travel time (265 fpm) = effective increase in trip length

or

(1.86 minutes) (265 fpm) = <u>492.9 ft.</u> of additional pathway length

Path (A)

1.	Total Unadjusted Length =	1780 ft.
2.	Total Adjusted Length (considering impedance factors)	2734 ft.
3.	Total Effective Increase in length due to Impedance Factors (2734.9 - 1780) =	954.9 ft.
4.	Percent Increase	54%
5.	Total Effective Increase in Travel Time $\frac{954.9}{265\ \text{FPM}}$ =	3.6 Min.

Path (B)

1.	Total Unadjusted Length =	1780 ft.
2.	Total Adjusted Length (considering impedance factors)	2132.2 ft.
3.	Total Effective Inc. In Length Due to Impendance Factors (2132.2 - 1780) =	343.2 ft.
4.	Percent Increase =	19%
5.	Total Effective Inc. in Travel Time $\frac{343.2}{265\ \text{FPM}}$ =	1.3 Min.

APPENDIX I: IMPEDANCE RELATED TO EFFECTIVE TRIP LENGTH - ENERGY AND TIME DELAY

Figure 6-10 graphically illustrates the effect of energy and time related pathway impedance factors upon desired trip length. The desired walking distance curve has been calculated from data collected for *6 cities. This curve shows the percentage of pedestrian trips (for all cities) that are made over specific distances. The curves illustrates that 50% of all trips are made within 500 feet of the point of origin.

Superimposed upon this trip-making curve are the pathway impedance factors and their associated range of impact upon trip length. Each impedance factor has the effect of adding time and distance to the pathway due to additional energy expenditure and time delay. The relative increase in both effective time and distance will have the impact of reducing trip-making propensities and consequently reducing pathway utilization. For example, reading from Figure 1 50% of all pedestrian trips are made within 500 feet of their origin. If a stair must be encountered along the pathway (up and down) the effect is to add 205 feet to the effective trip length. The total travel time would now be 705 feet, approximately a 41% increase. This could result in as much as a 15 to 20% decrease in utilization.

Figure 6-11: Impedance Related to Effective Trip Time - Energy and Time Delay

Figure 6-11 illustrates the combined effect of energy and time related pathway impedance factors relative to travel times rather then trip length. This diagram has been prepared on the same basis as Figure 1 however distance has been converted to time.

*"Desired distance walked in 6 cities," - Seattle, Pittsburgh, Dallas, Denver, Atlanta and Seattle (from parking facilities) H. Levinson, M.A.U.D.E.P. July 1973

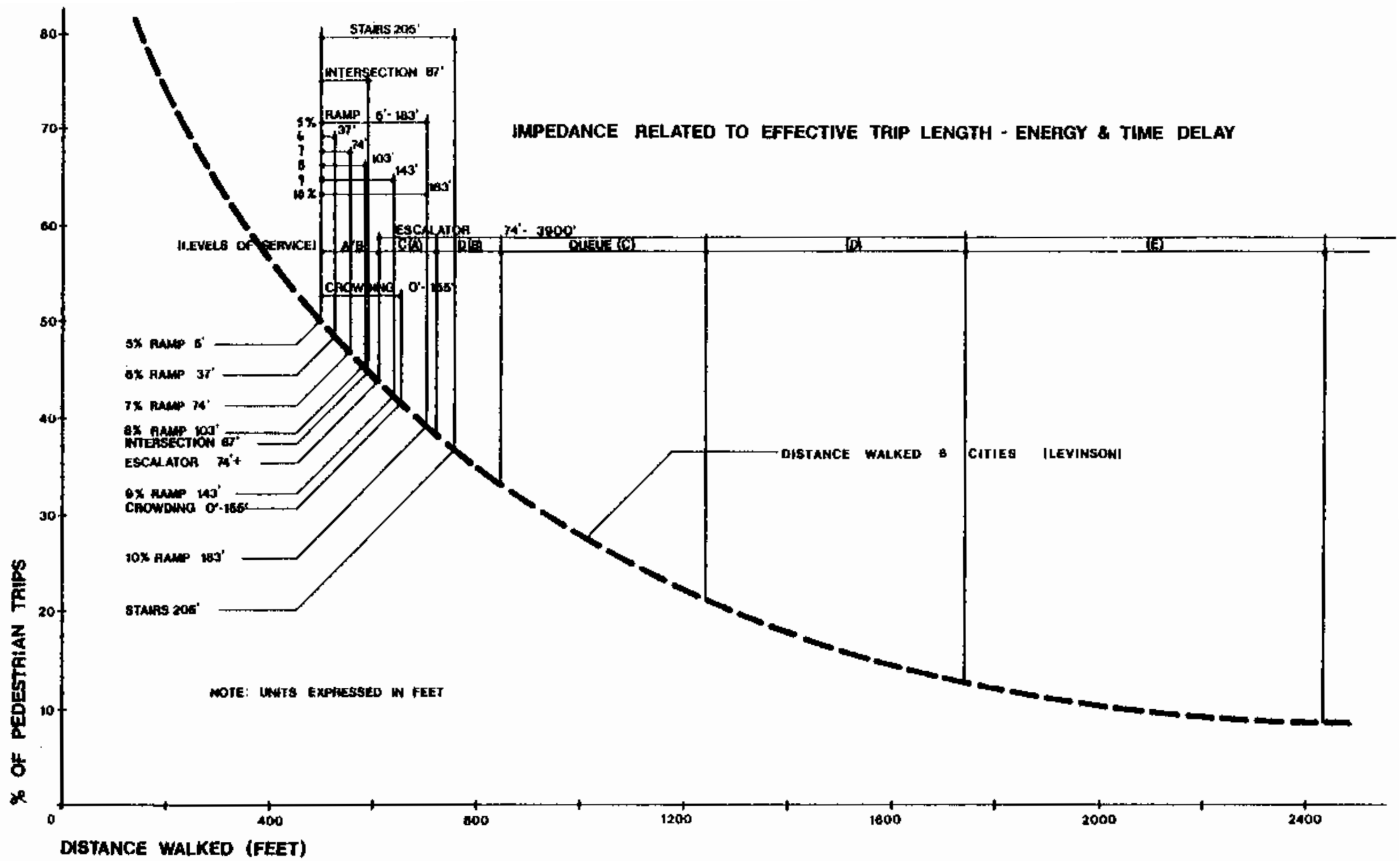

IMPEDANCE RELATED TO EFFECTIVE TRIP LENGTH - ENERGY & TIME DELAY
STAIRS 205'
INTERSECTION 67'
RAMP 5'-183'
5%
6
7
8
9
10%
37'
74'
103'
143'
183'
ESCALATOR 74'-3900'
(LEVELS OF SERVICE)
A/B
C(A)
D(B)
QUEUE (C)
(D)
(E)
CROWDING 0'-155'
5% RAMP 5'
6% RAMP 37'
7% RAMP 74'
8% RAMP 103'
INTERSECTION 67'
ESCALATOR 74'+
9% RAMP 143'
CROWDING 0'-155'
10% RAMP 183'
STAIRS 205'
DISTANCE WALKED 8 CITIES (LEVINSON)
NOTE: UNITS EXPRESSED IN FEET
% OF PEDESTRIAN TRIPS
80
70
60
50
40
30
20
10
0
400
800
1200
1600
2000
2400
DISTANCE WALKED (FEET)

FIGURE 6-10

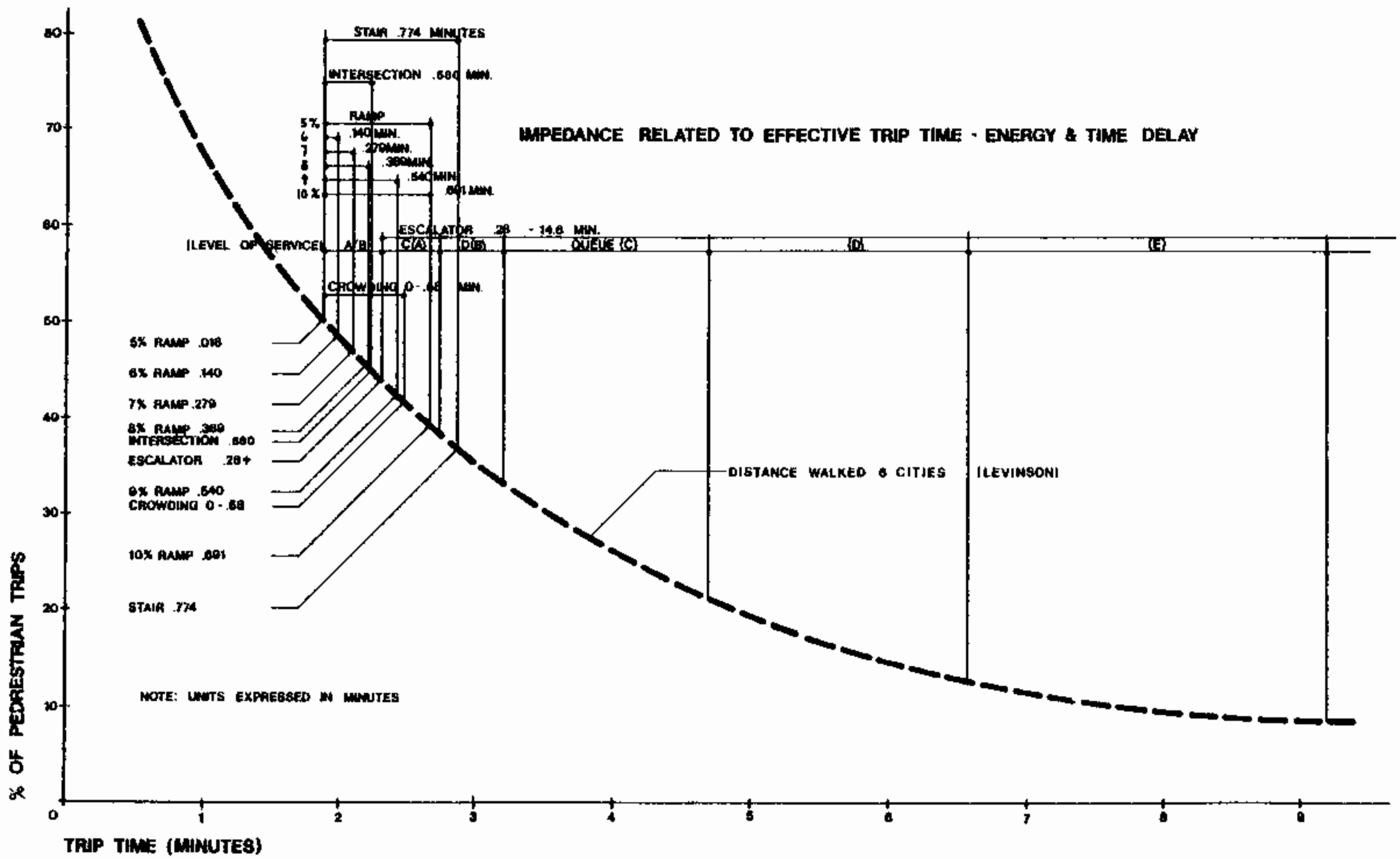

IMPEDANCE RELATED TO EFFECTIVE TRIP TIME - ENERGY & TIME DELAY
STAIR .774 MINUTES
INTERSECTION .680 MIN.
RAMP
.140 MIN.
.279MIN.
.369MIN.
.540MIN.
.691 MIN.
ESCALATOR .28 - 14.6 MIN.
LEVEL OF SERVICE A/B C(A) D(B) QUEUE (C) (D) (E)
5% RAMP .018
6% RAMP .140
7% RAMP .279
8% RAMP .369
INTERSECTION .680
ESCALATOR .28+
9% RAMP .540
CROWDING 0 - .68
10% RAMP .691
STAIR .774
DISTANCE WALKED 6 CITIES (LEVINSON)
NOTE: UNITS EXPRESSED IN MINUTES
% OF PEDESTRIAN TRIPS
TRIP TIME (MINUTES)

FIGURE 6-11

APPENDIX II - BACKGROUND DATA

A. Walking - Horizontal Surface

1. $C = 0.8V + 0.5$

   C = energy expended in CAL/MIN

   V = speed in Km/HR

2. Conversion of V in MPH (miles per hour)

   1m = 1 609 KM, therefore,

   $C = 0.8 \ (1.609) \ V + 0.5$

   $C = 1.29V + 0.5$

3. Assume average walking speed of 265 FPM (feet per min) or 3 MPH

4. $C = 1.29 \ (3) + 0.5$
   C = 4.4 CAL/MIN

   $C_F = \frac{4.4}{265} = 0.02$ CAL/FT

B. Stairs

1. Speed (up and conversions

   Vert. speed = 14.8 M/Min & 17.6M/Min. 1 meter = 3.281 ft.
   (V) Vert Speed = X_1 = 48.6 FPM & X2 57.75 FPM

2. Stair angle 32° (FRUIN)
   (S) Slope Speed = S (FPM)

   $S = \frac{\text{Vert Speed}}{\text{SIN } 32°}$

   $S_1 = \frac{\text{Vert Speed}}{.52992} = 92$ FPM

   S_2 = ... = 109 FPM

   (H) Horizontal Speed = y FPM

   Y = (S) COS 32°

   Y1 = (92) (.85) = 78 FPM

   Y2 = (109) (.85) = 92 FPM

Source: Passmore, Durnin Physiological Review Vol. 35
Oct. 1955 No. 4

The level equivalent average speed from Fruins study for the (UP) direction is 96.6 FPM. Therefore the vert. speed to be used from Table 4 will be 17.6 M/Min or 92 FPM (horizontal)

3. Energy Expenditure (from Table 4)

At 92 FPM for 59 kg or 158 lbs = 8.5 c/m
69 kg or 184 lbs = 8.4 c/m
75 kg or 200 lbs = 10.3 c/m

Regression Analysis

$$C = 0.40W + 1.73$$

If W = 170 lbs

$$C = 9.01 \text{ c/m}$$

W	158	200
C	8.5	10.3

4. Energy Exp. Up and Down

$$\text{Down} = \frac{1}{3} \text{ (Up}$$

$$X = \text{Up}$$

$$X + \frac{1}{3} = 9.01 \text{ c/m}$$

$$\frac{4x}{3} = 9.01 \text{ c/m}$$

$$x = \frac{3 \ (9.01)}{4}$$

$$x = 6.76 \text{ c/m}$$

$$x = 2.25 \text{ c/m}$$

9.01 c/m Up and Down

C. RAMPS

1.

Ramp Slope*	Speed		C/M	C/F
0 - 5%	3 MPH	265 FPM		
5 - 6	2.9	259		
6 - 7	2.8	253		
7 - 8	2.8	247		
8 - 9	2.7	241		
9 - 10	2.6	235		
10 - 11				

* 5 to 10% slope dec. speed by 11.5% Fruin (pg. 41) therefore for each 1% inc. in slope from 5% to 10% there is a 2.3% dec. in walking speed.

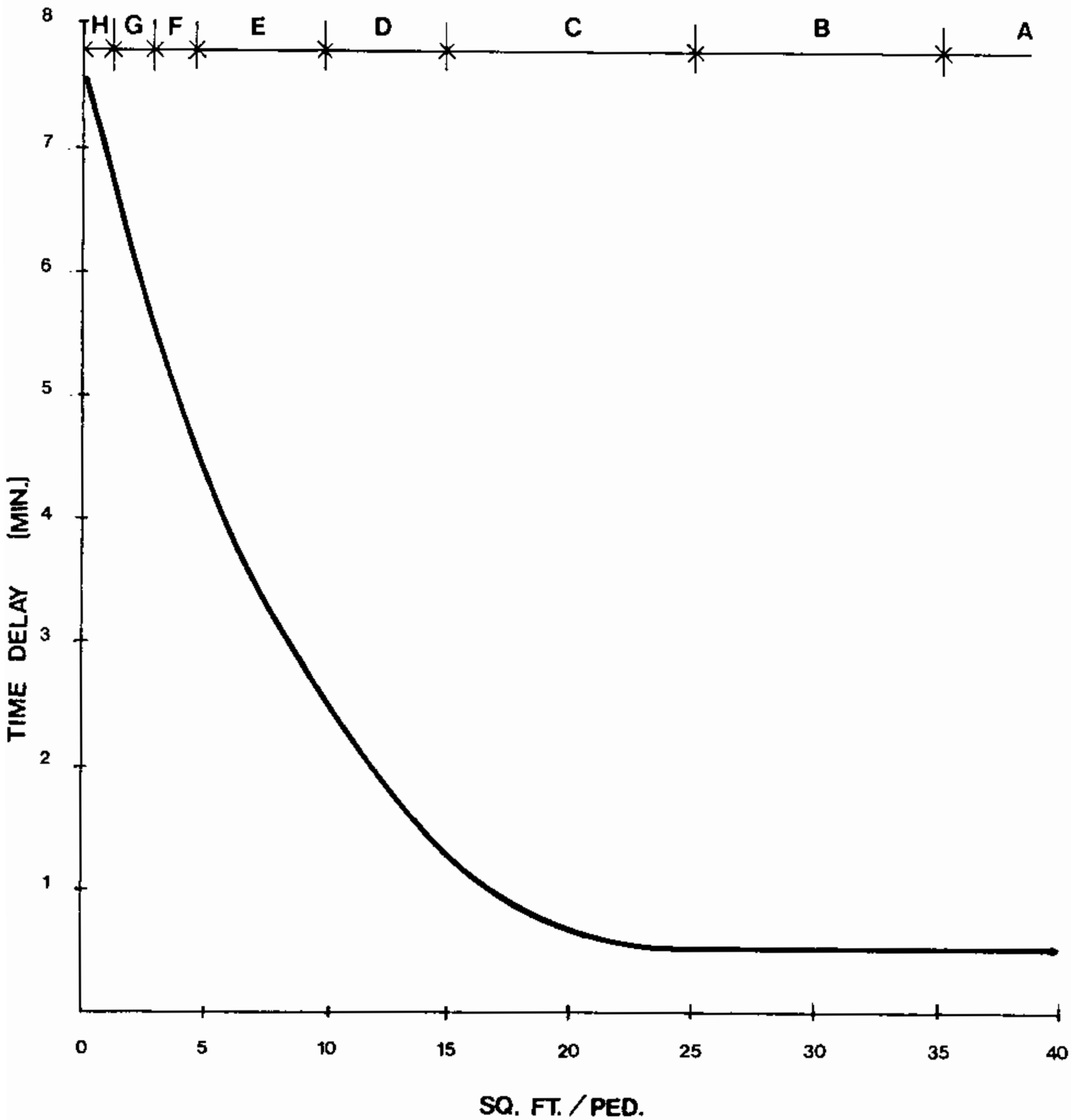

H
G
F
E
D
C
B
A
8
7
6
5
4
3
2
1
TIME DELAY (MIN.)
0
5
10
15
20
25
30
35
40
SQ. FT. / PED.

Figure 6-12

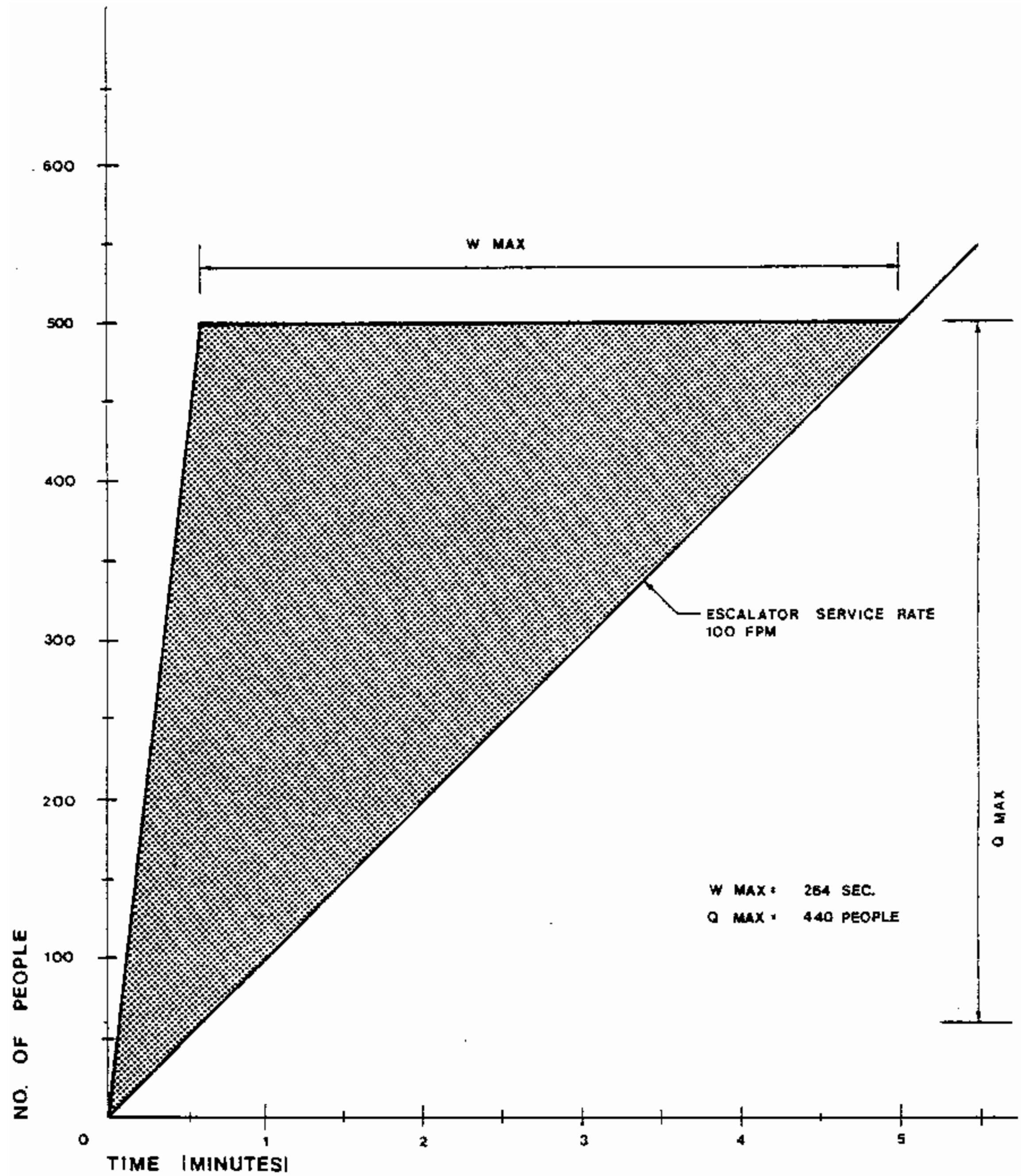
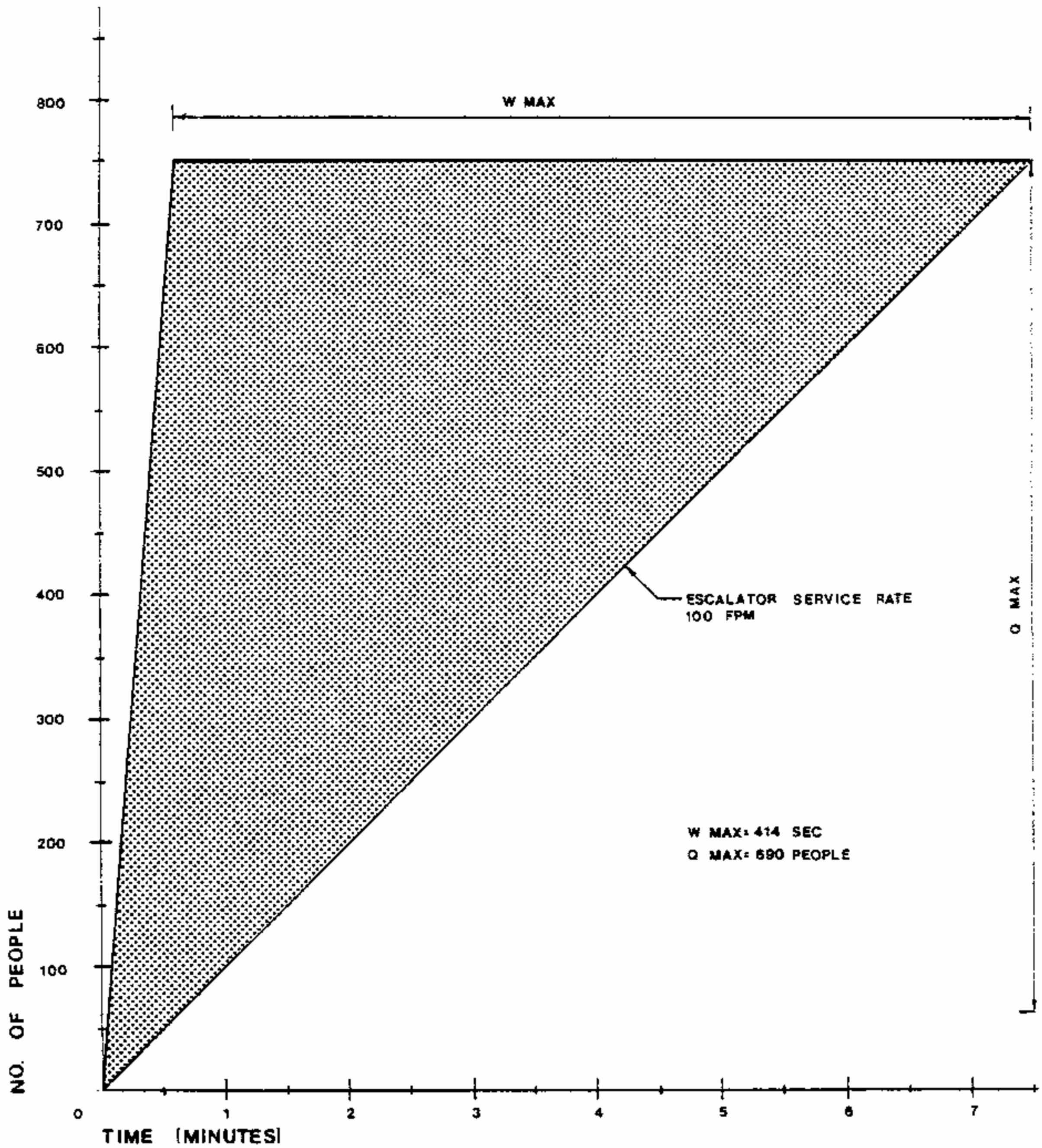
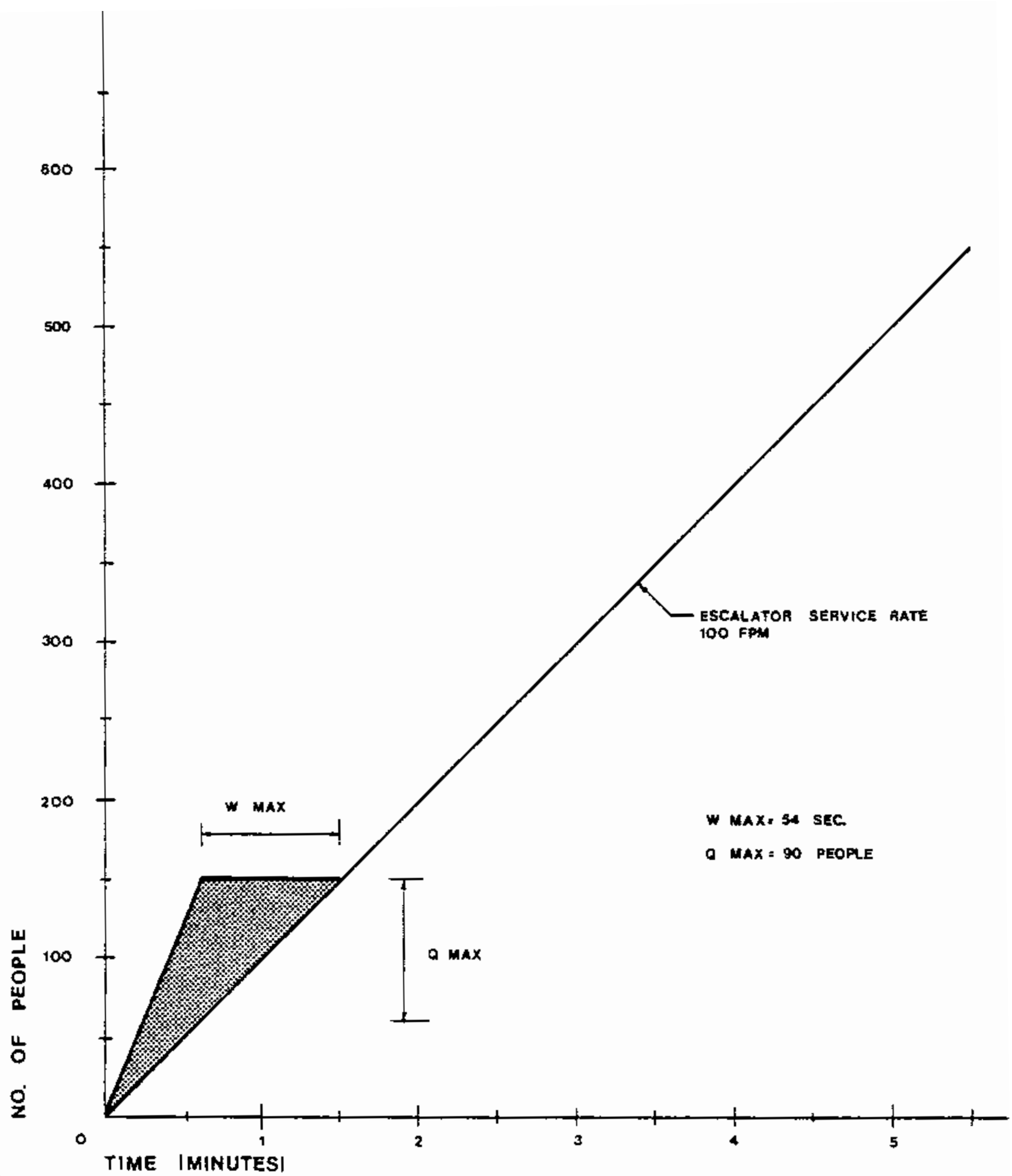

600
500
400
300
200
100
NO. OF PEOPLE
0
1
2
3
4
5
TIME (MINUTES)
W MAX
ESCALATOR SERVICE RATE
100 FPM
Q MAX
W MAX = 264 SEC.
Q MAX = 440 PEOPLE

Figure 6-13



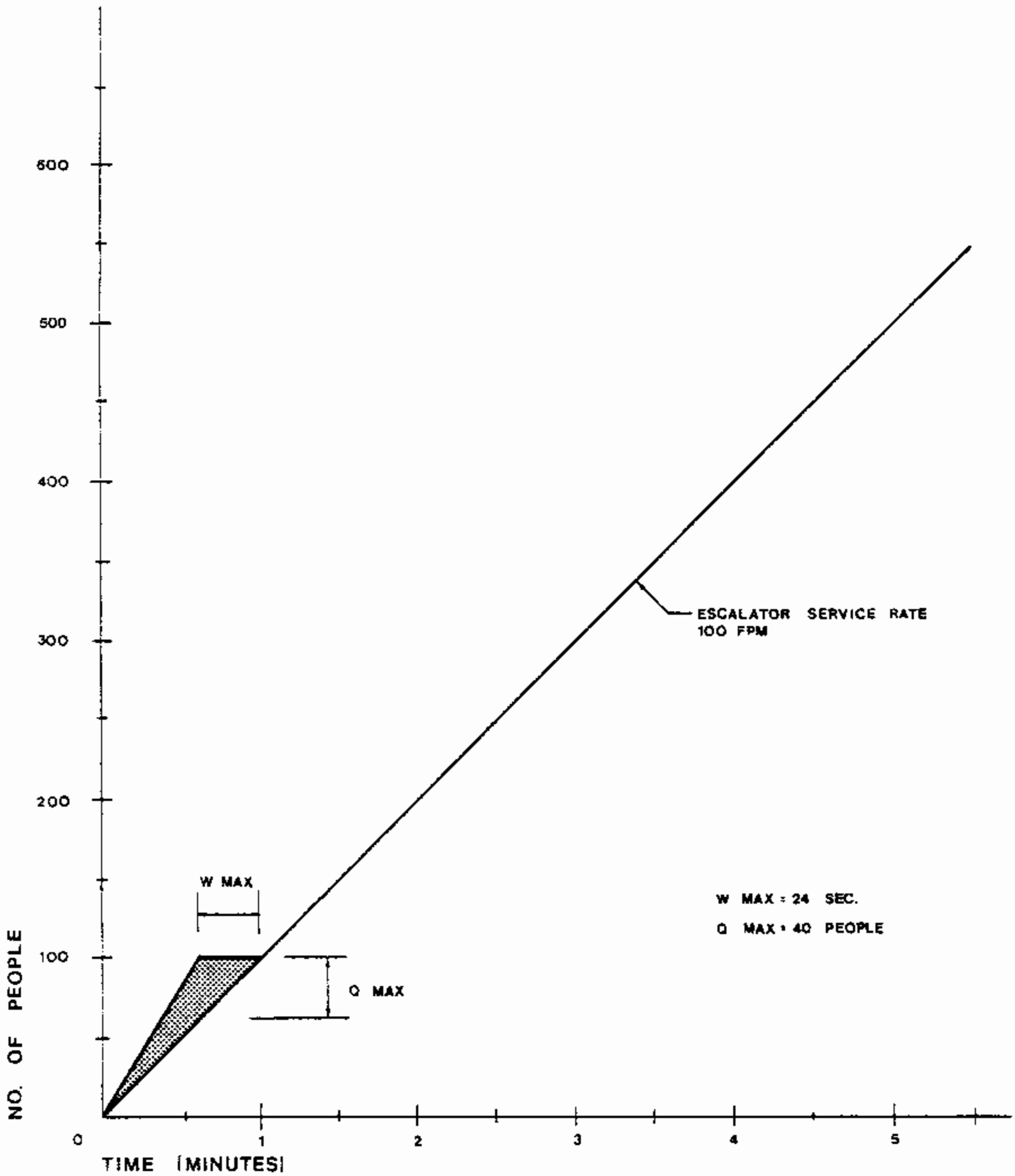
LEVEL QUEUE (E)

Figure 6-14



LEVEL (D)

Figure 6-15



LEVEL (C)

Figure 6-16

SUPPLEMENT 7

THE IMPACT OF VERTICAL DISPLACEMENT PATHWAY ELEMENTS ON INTER-CENTROID SEPARATION*

Numerous studies have shown that elements of vertical displacement along a pedestrian pathway, such as stairs or ramps, will impact upon trip making. Pedestrians resist grade change, even to the extent of incurring substantial risks in crossing roadways rather than utilize grade separated facilities such as tunnels or overcrossing. While some of this resistance can be explained by psychological factors (for example, negative reaction to pedestrian tunnels for reasons of security), it is also reasonable to assume that the physiological consideration of time, distance, and/or energy requirements, as perceived by pedestrians, can alter trip making decisions. Hence, vertical change elements modify the pedestrian perceived physical separation between two points. In this appendix, a method is suggested for approximating this perception.

The term "effective separation" will be used to describe the perceived separation, by pedestrians, between two points as a function of all factors - physiological, behavioral, psychological and so on. Measurement of effective separation has not been addressed, except in the most simplistic way, in prior research, and remains a topic for behavioral studies. The physical components of effective separation, while also not addressed to date, can be approximated using research conducted on pedestrian walking speed and energy expenditure under varying conditions. The approximations, developed in this appendix, can then be used to compute a measure of "nominal separation." The nominal separation represent an invariant measure, relative to level, unimpeded walking under average conditions, that accounts for the physical requirements of time, distance, and energy. More specifically, this appendix addresses the impact of movement. Ascending and descending stairs and ramps on the nominal separation of two points.

While data varies considerably, most research suggests that an appropriate average pedestrian speed on level surfaces is about 3 miles per hour, this is also the speed that minimizes energy expenditure (Corcoran, 1972). Also, the synthesis of numerous studies (Passmore and Durnin, 1955) indicates the relationship between energy expenditure and speed (over the range of 2-4 miles per hour) on level surfaces is given by -

$$C = 0.8\,V + 0.5,$$

where C is the energy expenditure expressed in KCAL/Minute, and V is the walking speed in KM/Hour. Making the appropriate calculations, the following nominal conditions for level walking are:

*This Supplement extends the concepts developed in Supplement 6 for stairs and ramps.

Distance 264 Feet Per Minute,

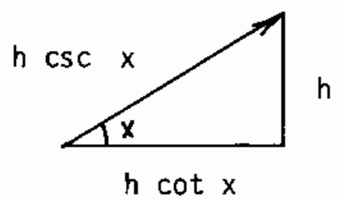
Energy 4.38 Calories Per Minute; or

1 Minute = 264 Feet = 4.38 Calories.

In the following sections these "equivalents" will be used to convert the physical time, distance and energy impacts of stairs and ramps to nominal measures of separation expressed in time units (usually minutes or seconds). The baseline for all measures is the level walking time requirement, and the stair/ramp impacts developed are always algebraically added to this baseline. The following discussion is divided into sections on the basis of time and energy impacts, and ascending and descending movement on stairs and ramps.

Stairs - Ascending - Walking Speed Component

The distance components for a stair of slope X and vertical grade change of h is given by -



The difference in time (Δ t) required to negotiate the horizontal distance, h cot x, on the stairs as opposed to the horizontal is

$$t = h \cot x \left[\frac{1}{R_1} \right] - \left[\frac{1}{R_2} \right]$$

where R, is the horizontal speed component associated with ascending the stair, and R_2 is the level walking speed.

Observations of stair climbing speeds of pedestrians incidcate that speed tends to decrease as stair slope increases. However, for simplicity and since sufficient data are not available, this effect will not be included here.

The following horizontal speed components (R_1) were observed (Fruin) for a wide range of pedestrians ascending stairs of approximately 30° slope:

Lower Bound	77 feet per minute
Mean	107 feet per minute
Upper Bound	120 feet per minute

For h = 10, x = 30°, 35° and 40°, R_1 having the values cited above, and R_2 equal to 264 feet per minute, the table shown in Figure 7-1 can be computed for t (in seconds):

	Stair Angle (x)		
	30°	35°	40°
Lower Bound	4.7	3.9	3.3
Mean	5.8	4.8	4.0
Upper Bound	9.6	7.9	6.6

FIGURE 7-1

Representative Delays (in seconds) due to change in Walking Speed on Stairs for Each 10' Change in Grade (Ascending Movement)

Stairs - Ascending - Energy Component

Energy expenditure data, summarized from several sources (by Passmore and Durnin), indicates that approximately 10 calories per minute are expended in going up and down stairs, with the energy required descending about one-third that required while ascending. Based on these data, the following values were used:

Ascending and Descending	-	10.0 calories per minute
Ascending Only	-	7.5 calories per minute
Descending Only	-	2.5 calories per minute

Then, the difference in energy requirements for a given horizontal component is the time spent ascending stairs times 7.5 calories/minutes minus the time spent in level walking times 4.4 calories/minutes. This difference in energy is converted to time by dividing 4.4 calories per minute. Hence,

$$t = h \cot x \quad \frac{7.5}{4.4} \cdot \left[\frac{1}{R_1}\right] - \left[\frac{1}{R_2}\right]$$

which yield the table shown in Figure 7-2.

	Stair Angle x		
	30°	35°	40°
Lower Bound	10.8	8.9	7.4
Mean	12.6	10.4	8.7
Upper Bound	19.1	15.7	13.1

FIGURE 7-2

Representative Delays (in seconds) Due to Change in Energy Expenditure on Stairs for Each 10' Change in Grade

(Ascending Movement)

Stairs - Descending - Walking Speed Component

Using the same approach as for ascending stairs, and similar data (Fruin) as follows:

Lower Bound	93 Feet Per Minute
Mean	142 Feet Per Minute
Upper Bound	183 Feet Per Minute

The values shown in Figure 7-3 were computed.

	Stair Angle (x)		
	30°	35°	40°
Lower Bound	1.7	1.4	1.2
Mean	3.4	2.8	2.3
Upper Bound	7.2	6.0	5.0

FIGURE 7-3

Representative Delays (in seconds) Due to Change in Walking Speed on Stairs for Each 10' Change in Grade

(Descending Movement)

Stairs - Descending - Energy Component

Using the same approach as for ascending stairs, and 2.5 calories per minute for the energy expended descending stairs, values as shown in Figure 7-4 were computed. Note that the negative values in the table represent time savings. This result occurs because the energy required for descending stairs is less than that required for level walking, and this saving more than compensates for the increased energy required due to the slower horizontal speed component. As the horizontal speed component of descent decreases, this saving is cancelled out by the energy expended over increased time.

	Stair Angle (x)		
	30°	35°	40°
Lower Bound	- 0.7	- 0.6	- 0.5
Mean	0.2	0.2	0.2
Upper Bound	2.4	2.0	1.7

FIGURE 7-4

Representative Delays (or Savings) (in Seconds) Due to Change in Walking Speed on Stairs for Each 10' Change in Grade (Descending Movement)

Ramps

The walking speed and energy components of nominal separation are derived using data summarized from numerous studies (McDonald). These studies indicated that as ramp slopes (gradients) varied from +40° (ascending) to -40° (descending), energy expenditure varied as a non-linear function of walking speed and gradient. Assuming that the walking speed also varies non-linearly from 132 feet per minute at a gradient of +40° to 264 feet per minute at 0° to 396 feet per minute at -40°, the data shown in Figure 7-5 were obtained.

Gradient (Degrees)	Slope Speed (Feet/Minute)	Energy Expenditure (Calories/Minute)
40	132	12.0
30	165	11.0
20	198	9.1
15	224	8.3
10	244	6.9
5	257	5.5
0	264	4.4
- 5	271	3.5
- 10	284	2.6
- 15	304	3.5
- 20	330	4.3
- 30	363	5.5
- 40	396	7.4

FIGURE 7-5

Data Used to Compute Walking Speed and Energy Time Equivalents for Ramps

Using the data in Figure 7-5, and methods similar to those employed in the stair analyses (note here that R_1 is the slope speed rather than the horizontal speed), the values shown in Figure 7-6 were obtained. The 40° extreme points were not included. For negative gradients, the increase walking speed cancels the time required to walk the increased slope distance, resulting in no added delay or savings.

Gradients	Time Equivalents Walking Speed	(seconds) Energy Expenditure
30	3.3	14.2
20	2.6	12.1
15	1.9	11.0
10	1.3	9.3
5	0.8	7.5
0	0	0
- 5	0	- 5.8
- 10	0	- 5.7
- 15	0	- 2.4
- 20	0	- 1.0
- 30	0	+ 2.0

FIGURE 7-6

Time Delays and Savings on Ramps Due To Change in Walking Speed and Energy Expenditure for Each 10' Change in Grade

In using the data provided in Figure 7-1 through 7-6, first compute the time to negotiate the entire horizontal trace of the pathway. Then, add the walking speed and energy expenditure time equivalents for each stair and ramp. The equivalents should be adjusted accordingly for changes in grade greater or less than 10 feet. Alternatively, measure the actual time required to negotiate the trip, and then add only the energy expenditure time equivalents.

SUPPLEMENT 8

THE DEVELOPMENT OF EFFECTIVE INTER-CENTROID SEPARATION MEASURES BASED ON TRIP PURPOSE

8.1 Statement of the Problem

We are interested in the typical situation wherein certain nodes of activity in an urban setting have been documented as generating or attracting relatively high volumes of pedestrians. That is, certain probable origins and destinations have been identified in terms of aggregate demand and the problem is to identify the most appropriate linkages amongst these designated nodes of activity. These linkage or pathway configurations are constrained by a number of variables, e.g., physical, economic, political; but whatever the constraints the objective is to realize a pedestrian environment which accommodates the population under analysis. The system has no purpose unless it is used and it will be used only if it responds to the behavioral objectives and propensities of the potential user. The problem, then, is to specify, design implement a pathway configuration which is predicted to maximize the probability that people will use the system in a particular way*.

8.2 Theoretical Perspective and Research Framework

Predicting human response to proposed environments is a difficult undertaking. We may never identify all of the variables which affect pathway choice and behavior and in addressing any real-world environment-behavior setting we are clearly dealing with multivariate phenomena compounded by the dynamics of changing propensities. Our review of the literature indicates that human pedestrian behavior is no doubt functionally related to certain classes and states of environmental variables. We will in this study attempt to identify the most salient variables operating in pedestrian environment-behavior settings and attempt to interrelate these in a manner which assist predictions regarding the viability of proposed systems. In examining the literature it is notable that research documenting relevant environment-behavior variables is uneven--is predicated on a somewhat disparate array of paradigms, perspectives, methodologies and types of settings. In order to develop a reasonably coherent approach to this task we offer the following general framework for environmental-behavioral design and management.

*That is, people may choose to use the system in an ostensibly, undesirable way, e.g., as a skateboard course, to mug passers-by, to consume dangerous drugs which merely points out that clear specification of the behaviors to be accommodated is a necessary part of the decision-making task.

The objective of environmental design is to solve human problems. A human problem emerges when there is a disparity between people's intentions (goals) and their accomplishments (behaviors)--a disparity between the way things _are_ and the way they _ought_ to be. If a large number of people, for example, see as their _goal_ to ambulate from point _A_ to point _B_ in, e.g., an efficient, pleasant, stimulating, safe manner, but cannot _do_ so due to a variety of impedances in the extant environment, this defines the need for a new (pedestrian) environment. It is clear that moving human systems from where they are to where they ought to be implicitly requires a change in human behavioral potential, as well as its maintenance in a new state.

Environmental systems, then, are systems of energy and matter interposed between people's behavioral objectives and antithetical elements in the general milieu (in the case of pedestrian behavioral objectives, e.g., automobiles, obstructions, muggers). Designed environments can thus be seen as _prosthetic_. Put in a different way, most researchers concur that environmental design and management should be directed toward the realization of an appropriate state of _congruence_ between environmental and behavioral structures. The lack of such congruence in a particular setting constitutes a problem to be solved. Such an objective implies that neither system must conform to nor form the other. The objective is rather to realize an environment-behavior _ensemble_ which fulfills the objectives and goals of the population under analysis within the constraints of the impinging external environment.

A decision to intervene in a human setting is occassioned by the recognition of unfulfilled goals, i.e., certain behaviors _are_ occurring which are incompatible with the goals of a population, and/or certain behaviors are _not_ occurring which should be if the goals are to be met. Clearly any design problem (as contrasted with a research problem) implies the need to realize and maintain _new behavioral states_; otherwise the setting would not require intervention. An understanding of behavior change and maintenance is thus at the core of planned intervention at any level of scale. What this leads to is a particular strategy of decision-making, i.e., a behavior-contingent approach, which has been documented elsewhere (Studer 1966, 1970, 1971) and will form the basis for subsequent methodological developments. But for the present let us look more closely at behavior change and maintenance form a perspective which places greatest emphasis on environmental variables.

8.3 Behavior Change and Maintenance Via Environmental Design and Management

The experimental analysis of behavior, sometimes called operant psychology, has produced profound and incontrovertible evidence for systematically relating aspects of environmental structure to observed behaviors. We are now witnessing an ever widening application of these principles in applied human settings. Whether or not operant principles and findings offer a complete explanation of human behavior, these embody powerful techniques for _controlling_ behavioral outcomes.

The methods for bringing operant behavior* under control of elements of the environment involve an analysis of the spatial/temporal relations (contiguity) between behavior and its positive or negative consequences. These consequences, i.e., reinforcers, affect the probabilities of the behavior's recurrence. When a reinforcer is made contingent on a particular form of behavior, this behavior is brought under its control. Behavior change and maintenance is effected through the spatial/temporal organization and management of the contingencies of reinforcement operating in a particular environment.

Another important area of behavior analysis of particular relevance is that of stimulus control (Terrace, 1966). When particular behaviors are iteratively reinforced in the presence of particular stimuli, these stimuli come to elicit those behaviors in the future. The process is discrimination learning and successful behavior in the designed environment depends heavily upon the participants' development of a complex system of discriminations. Environmental elements acquire "meaning" when discrimination of them leads to positively reinforcing events or the absence of aversive events. Thus we learn to emit appropriate responses to certain stimuli as we are differentially reinforced in their presence, i.e.:

1) $S^D \ldots R \rightarrow S^R$

2) $S^D \ldots R \rightarrow S^R$

Responses (R) emitted in the presence of the discriminative stimulus (S) are reinforced (S^D). The same responses (R^R) emitted in the presence of other stimuli (S^D) are not reinforced (S^R). The ways people learn to respond to elements in the environment, then, depends in great part on the history of consequences associated with these elements--upon the probabilities of e.g., danger, pleasure, social approval or disapproval, or simply completing a task successfully. Aspects of new environments come to elicit new behaviors through this dynamic. When a population is seen to respond uniformly to certain stimuli, i.e., shared symbols, this is a manisfestation of stimulus control (discrimination and generalization).

When behavior occurs, but is not reinforced, it will be extinguished, and the process of allowing behaviors to occur without reinforcement is called extinction. Operant conditioning can develop new forms of behavior through a procedure called shaping. The technique involved is one of selectively reinforcing certain aspects while allowing others to extinguish. A person comes to speak, draw or even problem-solve better when only those effective aspects of his repertory are reinforced. Once a behavior pattern has been established, it has been found that intermittent or random reinforcement is more powerful than continuous reinforcement, i.e., reinforcement after each response. Rate of response is the conventional

---

*Operant behavior, i.e., that which acts on the environment, is to be distinguished from respondent behavior. These latter "involunary" behaviors, i.e., the conditioned or unconditioned reflex, are effected when stimuli are paired with processes necessary to maintain homeostasis and well-being of an organism, e.g., eating, seeking shelter, combating an attacking enemy.

datum of basic and applied operant research, and characteristics of extinction have been systematically controlled through the use of various schedules of reinforcement. Relevant and interesting as this is, it will not be further explored here.

Bandura (1969, 1971) has explored another operant-based phenomenon, known as social modeling, which has interesting implications for interpersonal behaviors involved in such public settings as urban pathways. Bandura's findings reveal that individual's behavior is modified via vicarious reinforcement. One individual observing another's interaction with the environment, i.e., the contingencies of reinforcement operating, appears to learn in a manner closely approximating that of experiencing (even complex) contingencies directly. This essentially one: many learning phenomenon thus explains a great deal about social or aggregate learning from an operant perspective.

Behavioral technology is the application of operant principles developed in the experimental laboratory, two components of which require consideration: 1) contingency management and 2) stimulus control. These are the principal techniques effecting behavior change and maintenance. Contingency management simply involves arranging the environment such that the probabilities of reinforcing consequences are made contingent upon, increase as a function of, appropriate behaviors. As noted above, acquisition of stimulus control occurs when certain behaviors are iteratively reinforced in the presence of certain stimuli.

Behavior modification utilizing both contingency management and/or stimulus control involves the following sequential components: 1) baseline analysis of the extant environmental-behavioral structures, 2) development of new behavioral baseline, 5) iteration of 3 and 4. This well-documented behavior modification strategy clearly has application to a problem situation where environmental alteration is indicated.

Systematic behavior modification is obviously not accomplished in an "all or none" fashion. Research in human learning confirms that transformation from one complex state to another involves a series of intermediate states, i.e., behavioral shaping or successive approximation. Modifying behavior toward a viable or specified state (e.g., stimulus control of certain features of the environment via the acquisition of appropriate stimulus discriminations) involves multiple and varying presentations. Appropriate responses to complex, high-performance environments generally come about as an organism acquires increasingly complex repertoires. An environment which reinforces such acquisitions is one which is constantly modified.

A program of extensive behavior change for most human settings appears as an extremely complex enterprise. If entirely new repertories were required of all participants, the task would, of course, be impossible. Relative to the total behaviors emitted in a setting, the elements requiring modification represent but a small subset. Three functional elements are involved: 1) strengthening of extant requisite behaviors, 2) extinction of undesirable behaviors, and 3) shaping of new requisite behaviors. That is, some of the behaviors in extant repertoires are assumed to remain, some are intensified and some are eliminated.

8.4 A General Strategy For Pathway Choice and Behavior Analysis

The above contains only the barest elements of a complex explication of the principles of behavior change and maintenance, but will suffice to identify an approach to the problem at hand.

Human behavior can be seen as a product of: 1) phylogeny, i.e., the individual's genetic endowment, 2) ontogeny, i.e., the individual's history of interaction with the environment (reinforcement history), and 3) the existing environment (contingencies operating therein). In a given population we of course find differences amongst individual phylogenies and ontogenies. However, we also find great similarities. These differences and similarities define the probabilities that a population will respond somewhat uniformily to a given environment, e.g., a pedway system. It should be noted, however, that these probabilities can be seen to change in the presence of a particular environment via learning.

That people will maintain contact with aspects of the environment which generate favorable consequences is obvious. The first question, then, is what environmental consequences does a population perceive as either positive or aversive, i.e., reinforcing. When we speak of propensities we are really speaking of potential reinforcers which maintain behavior. What is seen as reinforcing by a particular population depends on, among other things, their objectives and their environmental history. In short, if we wish to predict or to modify the probabilities of a population choosing and utilizing a pathway configuration we must understand which environmental variables, and states of these variables are reinforcing to that population.

The methods of probing a population's propensities in order to predict the initial response to a system and to subsequently alter these, then, is the central task of this study. The most reliable approach for the planner is to identify the propensities of a population in a particular context, however, the literature suggests that certain variables (i.e., reinforcers) have been recurringly identified as relevant in influencing pathway choice and behavior.

In any decision-making context of interest the planner is faced with a situation wherein several possible routes are available to a pedestrian; therefore the task is to comparatively assess certain attributes or variable states in order to predict the viability of the system to be implemented i.e., on the whole is it more reinforcing to the user than other available pathways?

In should be reemphasized, however, that the initial state of the ensemble can be subsequently altered via organization of the contingencies of reinforcement, i.e., learning. The strategy suggested is one which attends to the dynamics of behavior change. That is, once the reinforcement potential of a population is understood, contingencies can be programmed to increase and maintain use of pathway. For example, if people are included to seek stimulation or novelty in their day-to-day use of urban systems, an appropriate pathway configuration might be one in which stimulus complexity is programmatically introduced in order that users be constantly discovering new stimulus elements in their day-to-day trip making. Alternatively the environment might be constantly altered (i.e., state-changing) with respect to certain dimensions in order to present new stimulation. Issues related to the programming of pathway environments to facilitate learning will not be further discussed in this report, but it is understood that post implementation environmental management is an integral aspect of the planning task.

In any event the following appear to require attention in assessing the probabilities of pathway choice and behavior (see chart below).

POPULATION PARAMETERS

In order to assess the propensities (reinforcement potential) of a population, the following partitions appear relevant:

a. Trip Purpose*

1) Home
2) Work
3) Shopping
4) Recreation/Social
5) Other

b. Developmental Category

1) Children
2) Adolescents
3) Adults
4) Elderly

c. Socio-Economic

1) Low
2) Middle
3) High

d. Other

1) Ethnic
2) Sex
3) Disabled
4) Geographic origins
5) Other

*That is, a trip purpose is defined by combinations of these.

The issue here is that the population of users as partitioned and analyzed above will reveal certain propensities, constraints and objectives which influence the probabilities of use. A person in a home-work trip seeks a direct, time-conserving route, the same person in a shopping mode seeks access to various commercial establishments. The same person taking a recreational stroll seeks still other activities and stimulation. Likewise children, adolescents, adults and the elderly often have quite different preferences and behavioral objectives when using a pathway. Users are, of course, influenced (reinforced) by composition of the population using the pathway, as well as the kinds of facilities accessible to and from it. Various ethnic groups may have different requirements (e.g., personal space tolerances); and even sex differences in pedestrian response patterns have been identified. The above categories obviously overlap and interact. The task is to identify these interactions and overlappings to ascertain a population profile to be accommodated.

BEHAVIORAL OBJECTIVES

Each of the above populations implies a set of behavioral objectives (as well as a set of propensities) to which the pedestrian system must respond. Most of these objectives are ostensibly well known, however, these should ideally be empirically documented for the population under analysis for the results may be revealing. Behavioral objectives are simply operationalized goals and these must be generated for the particular set of population parameters deemed relevant, e.g., home to work trips by adults in the middle income category with a particular distribution of ethnic, sex and disabled persons.

ENVIRONMENTAL VARIABLES

The behavioral objectives discussed above are those to be accommodated/elicited by the environment to be designed and implemented. What is required is documentation of those elements (variables) and states of these which affect those (pedestrian) behaviors (behavioral objectives) defined above. To put it another way, what states of which environmental variables reinforce the target behaviors? Those variables are reinforcing which when presented as a consequence of certain behaviors increase the probability of those behaviors' recurrence. The circularity here is apparent in that empirical documentation of the reinforcing properties of particular environmental elements, components, and states is derived from an observation of response frequencies. On the other hand the planner/designer is charged with predicting in advance which elements and states will reinforce desired behavior. There are methods (to be documented) for dealing with this empirical problem, but first let us attempt to identify some of the most salient variables documented in the literature as influencing pathway choice and behavior. The following classes of variables are not all discrete; they differentially influence pathway choice and behavior, and they obviously interact to produce particular behavioral outcomes. Also each of these should be assessed in terms of both real and perceived states. Finally, each of these should ideally be assessed for each of the above population partitions selected for analysis. In order to make our task tractable, we will assume for the remainder of this study a general adult population involved in three trip purposes: home to work, shopping, and social/recreational. The variables which we will attempt to assess include (alphabetically):

1. Accessibility

Pedestrians will use that pathway which is accessible from desirable origins and from which access is probable to desirable destinations. An analysis of the probable desired origins and destinations of the target population is required. Again the real versus the perceived accessibility requires documentation.

2. Amenities

This class of variables is, of course, closely associated with attractiveness, but is identified separately as constituting a more "utilitarian" dimension. That is, in addition to the reinforcement of stimulus quality, e.g., visual, sonic, people require (are reinforced by) certain physical accommodations, e.g., benches, fountains, rest rooms. The pathways responding most fully to these requirements are generally more reinforcing than those lacking certain amenities.

3. Attractiveness

Pedestrians will use those pathways which are simply attractive to them. This is an attribute which is, in some respects, difficult to measure before an environment has been implemented. That is, an individual's or population's response to particular stimulus configurations is dependent upon their conditioning history. In general, humans are (depending on contextural variables) stimulus seeking, e.g., novelty, complexity. That is, they seek certain dimensions and states of social and physical stimulation and are reinforced by environments which generate desired stimuli. Assessing a populations propensities (reinforcement potential) in this regard requires implementation of certain techniques to externalize and measure these. In the end, however, the designer must rely on his/her experience and expertise in hypothesizing response probabilities given particular proposed configurations. In order to truly respond to a population's propensities in terms of appropriate stimuli, certain state changing elements are suggested, not only because of the uncertainties of initially attaining a good fit, but also to accommodate the dynamics of changing propensities. An integral dimension of attractiveness is also maintenance of the pathway and thus is an important variable requiring assessment.

4. Comfort

Pedestrians will select and use those pathways which maximize their a) physiological and b) psychological comfort. Pedestrian environments which result in invasion of an individual's personal space are aversive and will be avoided or escaped from. Fear of criminal activity or the possibility of encountering persons "different from themselves" can likewise affect psychological comfort. Those pathways which are likely to produce noxious or threatening stimuli to the individual's physiological state will likewise be avoided. Certain standards for capacity have been developed based on perceptions of crowding and physical impedance. Other measures of noxious stimuli, e.g., sonic, olfactory, visual, and appropriate states of these required for human functioning have been empirically documented.

5. Distance

Distance, of course, interacts integrally with time; however, these can and should be measured separately. In the case of distance, as contrasted with time, the user is expending physical energy as a function distance. Again real and perceived measures are required.

6. Impedance

This is a class of variables which essentially includes a) any spatial deviation (either horizontal and vertical) from a straight line between the users origin and destination, or b) any time which is lost--which deviates from that required to ambulate between the origin and destination along a straight line at a given walking speed. Both real and perceived impedance must be measured via units of deviation from the optimum (unimpeded progress from origin to destination).

7. Information

Users are generally reinforced for using pathways which are the least ambiguous--which involve the least risk of being confused or lost. A pedestrian will seek and use those pathways which are known to lead to desired locations. Such knowledge or information can be learned, of course, and an important dimension of a pedway environmental design is to facilitate learning of appropriate codes, cues, etc. (via stimulus control acquisition).

8. Safety

Pedestrians will use those pathways which reduce the risk of bodily harm. A safety index (measure) would be arrived at by assessing the probabilities of encountering an accident or incident which is in turn a product of a particular pathway configuration. Accidents can occur when pedestrians encounter motorized vehicles, bicycles, stairs, ramps, escalators.

9. Time

The intensity of time conservation as a reinforcer for utilizing a pathway is dependent upon the user's status as noted under population parameters, e.g., trip purpose. Almost any set of data, however, documents the conservation of time as a most salient reinforcer for selecting a pathway. Real time is an easily measured variable. Perceived time is more difficult but accessible via a number of empirical methods.

POPULATION VARIABLES (P)	Behavioral Objectives (R_r)	Environmental Variables (E_n)	Units of Analysis	Method of Assessment		Variable State		Response Probability $Pr(R_r \mid P_{ijkm})$	Comparative Assessment
				Real	Perceived	Real	Perceived		
TRIP PURPOSE 1. Home 2. Work 3. Shop 4. Rec/Soc 5. Other	r_1,	1. ACCESSIBILITY 2. AMENITIES 3. ATTRACTIVENESS						$Pr(r_1)$,	$W_1 = Pr(r_1)$, $Pr(r_2)$, $Pr(r_3)$, ⋮ $Pr(r_n)$
DEVELOP. STATE 1. Children 2. Adolescents 3. Adults 4. Elderly	r_2,	4. COMFORT Physiological Psychological 5. DISTANCE						$Pr(r_2)$,	$W_2 = Pr(r_1)$,
SOCIO ECONOMIC 1. Low 2. Middle 3. High	r_3, . .	6. IMPEDANCE (Energy) 7. INFORMATION 8. SAFETY						$Pr(r_3)$, . .	$Pr(r_2)$ $Pr(r_3)$, ⋮ $Pr(r_n)$
OTHER 1. Ethnic 2. Sex 3. Disabled 4. Geog. Origins 5. Other	. r_n	9. TIME						. $Pr(r_n)$	$W_3 = Pr(r_1)$, $Pr(r_2)$, $Pr(r_3)$, ⋮ $Pr(r_n)$
		To be assessed for each pathway system (W) under analysis							⋮ $W_n = Pr(r_1)$, $Pr(r_2)$, $Pr(r_3)$, ⋮ $Pr(r_n)$,

FIGURE 8-1

Pathway Choice And Behavior Assessment Framework

$P(\{t\},\{d\},\{s\},\{o\}) \equiv$ the population of pedestrian users, where
$\{t\} \equiv$ the set of possible trip purposes
$\{d\} \equiv$ the set of possible developmental states
$\{s\} \equiv$ the set of possible s.e.s. states
$\{o\} \equiv$ the set of possible other states

$P_{ijkm} \equiv$ the population selected for analysis

$P_{ijkm} = P_{\{t_i\},\{d_j\},\{s_k\},\{o_m\}}$, where
$\{t_i\}$ = a subset of $\{t\}$
$\{d_j\}$ = a subset of $\{d\}$
$\{s_k\}$ = a subset of $\{s\}$
$\{o_m\}$ = a subset of $\{o\}$

$W \equiv$ Pathway under analysis

$R_r \equiv$ the set of behavioral objectives for pathway

$R_r(P_{ijkm})$, where $r = 1,2,3...n$

$E_n \equiv$ Pathway environmental variables, where $n = 1,2,3...9$

$f_w(P_{ijkm},E_n) \equiv$ raw score for W

$tf_w(P_{ijkm},E_n) = g_w(P_{ijkm},E_n) \equiv$ adjusted score for W

$h_n \equiv$ Weighting, where $n = 1,2,3...9$

$\sum_{n=1}^{9} h_n g_w(P_{ijkm},E_n)$ = Pathway score for W

Decision rule: select W such that

$$\underset{W}{\text{Max.}} \left\{ \sum_{n=1}^{9} h_n g_w(P_{ijkm},E_n) \right\}$$

That is,

$$Pr\{R_r | P_{ijkm}\} = \frac{\sum_{n=1}^{9} h_n g_w(P_{ijkm},E_n)}{\sum_{w=1}^{n} \sum_{n=1}^{9} h_n g_w(P_{ijkm},E_n)}$$

FIGURE 8-2

Pathway Choice And Behavior Assessment Framework

The arguments developed thus far and the nature of the analytic task involved in (comparatively) assessing pathway choice is summarized in Figures 8-1 and 8-2.

8.5 Toward An Empirical Assessment of Pathway Choice and Behavior

Having laid out the general issues related to predicting pathway choice for a particular population, we set about to develop an instrument to measure these phenomena. Our initial strategy was directed toward development of an instrument which could be used by planners and designers to probe the pathway choice propensities of a particular population in a particular setting. Our first task was to identify the appropriate units of analysis and methods of measuring the variables influencing pathway choice.

Units and Methods of Assessment

1. ACCESSIBILITY

Units - Number of access links to/from pathway to desired nodes x impedance units re: access links x time/distance to node.

Method - Count access links; count impedance units along access link; measure distance, and time from pathway to node.
- To measure perceived access subjects might respond to a set of questions requiring above information units or subject them to a set of stimulus elements.

Score - Ratio of perceived accessibility to actual (determined via calculation of real time, distance, impedance, etc.). This will yield perceived accessibility.

2. AMENITIES

Units - Amenity x value of amenity

Method - Probe population re: preference rating of amenities, a_1, a_2, a_3 ....a_n
- Present subjects with list of amenities from pathway and have them rated for value to subject.

Score - Total rating amenity values multiplied by number of each.

3. ATTRACTIVENESS

3.1 Stimulus Qualities:

Units - Scale rating e.g.
-- appealing-unappealing
-- complex-simple
-- ambiguous-clear
-- orderly-disorderly

Method - Present some general stimuli (related to pathways) to subjects and record their preferences along a scale; score and summarize responses.

- Have respondents consider extant and/or proposed pathways in terms of above qualities; observe reponses to them and/or elicit responses from subjects (slides, etc.); thus developing preference ratings.

3.2 Maintenance:

Units - Dollars allocated for maintenance/sq. ft. of pathway.

Method - Ascertain dollars allocated for maintenance; calculate square footage of pathway.

Score - Ratio of actual to perceived maintenance.

4. COMFORT

Units - Physiological--units of :

-- atmospheric
  temperature (degrees)
  humidity (% moisture)
  movement (velocity)
  composition
    chemical
    pressure
  pressure
-- luminous (lumins)
-- sonic (decibels)

- Psychological
-- probability of invasion of personal space
-- probability of encountering those with criminal intent
-- sensory overload, underload, non-patterning
-- probability of contact with alien or hostile s.e.s. groups
-- perceived physiological states, e.g., "seems busy," "seems noisy."

Method - Develop an attitude inventory with scales covering, e.g., personal space and privacy, sensory input, including the physiological variables (noise, etc.), and anxiety over interpersonal transactions, (e.g., with unfamiliar people, criminal elements)

Score - Attitude score.

5. DISTANCE

Units - Miles / Kilometers
Feet or Meters
Inches / Centimeters

Method - Measure walking trip distance along pathway in miles, feet, inches (or in metric units) to get real value.
- Probe population sample re: Their estimate of distance(s) between nodes along pathway, convert other units, e.g., "Blocks," into miles, feet, inches to get perceived value.

Score - Ratio of real distance to perceived distance, dividing real by perceived. Thus, the larger the score, the more underperceived is the length of the trip.

6. IMPEDANCE

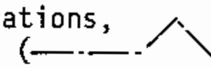
Units - Units of deviations from the optimum configuration, i.e., impedance unit (spatial and temporal).

Method - Develop impedance units (from the literature) for each environmental event, e.g., stopping for a signal light, crossing (unsignalled) intersection, 90° turn.
- Document spatial and temporal impedances along pathway and multiply by impedance units.
- To measure perceived impedance subjects respond to a set of questions (or stimuli) probing their comprehension of the various impedance elements in the pathway.

Score - Ratio of perceived impedance elements to actual impedance elements. When actual is divided by perceived, a higher score will indicate that the impedance was underperceived.

7. INFORMATION

Units - Actual route(s) to defined locations along the pathway, i.e., nodes, links, codes, landmarks.
- Externalized knowledge of individuals re: defined locations along the pathway, i.e., nodes, links, codes, landmarks.

Method - Delineate nominative routes to various locations, e.g., depicted in two dimensional impoverished maps ()
- Probe selected subjects' knowledge of routes via, e.g., map drawings, way finding via impoverished maps (as above) or via response to a set of appropriate questions.
- Reduce the second to elements of the first and measure deviations (errors).

- A cognitive mapping or way finding task is used, where the respondent is presented with an impoverished two-dimensional map of the pathway. The task is to complete the map by providing information: street names, landmarks, nodes, links, etc. The quality of the information is the total number of bits of information provided.

Score - Accuracy or error rate is the percentage of correct bits of information when the total number of bits provided are divided into the number of correctly labeled and/or identified bits. Quantity is the untransformed total score.

8. SAFETY

Units - Threatening person-object interactions.
- Threatening person-person interactions.

Method - Real-person object; person-person threats -- count the person-object interactions and multiply by weights (probability x severity) assigned, e.g., crossing two lanes of traffic, going up a stairway, going down a stairway.
-- count the possible person-person threatening encounters and multiply by weights (probability x severity)
- Perceived person-person/person-object threats
-- Probe (via questionnaire, stimulus presentations) subjects' assessment of number and danger of person-object, person-person encounters and severity of each.

Score - Ratio of actual person-object/person-person threats (based on empirical documentation) to perceived person-object/person-person threats.

9. TIME

Units - Minutes/seconds.

Method - Measure pathway trip in min., sec. x normal walking speed to get real value.
- Probe population sample re: their estimate of typical elapsed time between origins (s) and destinations (s) in min., sec., to get perceived value.

Score - Ratio of real to perceived time, with real time over perceived time. Thus, the larger the score, the more under-perceived is the duration of the trip.

8.6 Development of the Empirical Instrument

Development of an appropriate instrument to empirically assess pathway choice propensities involved four (4) iterations. Our initial approach was to design a general questionnaire which could be administered to each particular setting (population) under analysis. This questionnaire probed in considerable detail the propensities of a particular population vis-a-vis the ten classes of variables describing the pathway environment. As was the case in all subsequent approaches to questionnaire design, we assumed that the task was to predict a population's choice and use of a pathway given an origin and destination, and the availability of alternative pedestrian routes between these points (both existing and proposed). The initial instrument developed for this predictive purpose is included in the appendix of this report. Examination of this instrument reveals a high level of detail and its administration to an appropriate sample of a target population in a particular setting would, we feel, yield highly reliable predictions regarding pathway choice and use. The further development of this instrument was, however, abandoned after extensive consultation with the prime contractor and other members of the research team on the grounds that the instrument was simply too complicated to administer by planners and designers in most urban settings of interest. We thus initiated an alternative approach to the problem of predicting pathway choice and behavior. It was understood that a more practical and efficient approach was required for use in the field, but it was also clear that acceptance of a less powerful empirical instrument (vis-a-vis behavioral predictions) was inevitable. What we were seeking to develop was an instrument which professional planners/designers could execute in the field within a reasonable time frame. We needed an instrument which would facilitate predictions of route selection given that the actual environmental characteristics of the alternative pathways between two points could be described. To realize such an instrument requires that we have an understanding of people's preference orderings in terms of the set of environmental attributes described above, i.e., how do pedestrians rank and weight these ten attributes in choosing a walking route.

One approach was thus to move toward a general understanding of pedestrian pathway choice strategies. We began development of a questionnaire to be administered to a typical (representative) population of pedestrians the purpose of which was to develop weighted preference orderings of the pathway environmental variables. We first developed a fairly complex questionnaire to assess people's pathway propensities in the context of the trip purposes: work, shopping and social/recreational. In general, we included at least those items to assess each of the ten variables. The purpose was to probe three different response modes; i.e., affect, use, and attitude. This questionnaire, which is included in the appendix, was pilot tested on seventy (70) representative subjects. Results of the pretest indicated a great deal of stability across all three response modes with respect to all ten variables.

The results of the pretest thus enabled us to redesign the questionnaire to (more economically) include only a single item for each variable for each trip purpose. In addition, we included a section requiring respondents to rank order the pathway variables for each trip purpose.

This revised questionnaire was responded to by over 25 experts in the area of pedestrian behavior. These experts were asked not only to comment on the general approach, the variables, and items included, but also to respond to the questionnaire items themselves in terms of how they would expect the average pedestrian to respond to these. This questionnaire is included in the appendix. While the actual results of the survey itself were somewhat inconclusive*, these experts offered a number of invaluable criticisms and suggestions. These were incorporated into the final instrument which was administered and analyzed as outlined below.

8.7 Empirical Assessment of Pedestrian Pathway Choice and Behavior

Our review of the literature on pedestrian pathway choice and behavior yielded ten (10) basic environmental attributes or variables as relevant. A questionnaire was developed and refined which contained a description of the intention of our study (i.e., to better plan pedestrian pathways), and three separate scenarios. Scenario One (Work Trip) asked the respondent to imagine that he/she had taken a position with a firm in the downtown area of a city, and that it was feasible to walk to and from work. Scenario Two (Social/Recreational Trip) asked the respondent to imagine that he/she were selecting a pathway for social or recreational purposes, and Scenario Three (Shopping Trip) asked the respondent to imagine that he/she were selecting a pathway for the purposes of shopping at various establishments. A full example of the scenarios and the complete questionnaire is appended.

After each scenario, the respondent was asked to rate how important to his/her choice and use of a particular pathway was each of the factors. The factors were presented in a seven-point Likert type format, with one = very important and seven = very unimportant. Four was used as a neutral point. The factors were explained in depth prior to the first scenario. The following definitions were presented:

ACCESSIBILITY--How accessible are the various places you may want to reach to your major location (work or home), such as shops, department stores, friends, parks, restaurants?

*The experts tended to concentrate on the nature of the items and their role as critic of the questionnaire rather than responding to the items themselves, with the result that many of the questionnaires were not completed. We thus did not develop a complet analysis of these.

AMENITIES--As you contemplate the selection of a route you may consider various amenities, such as benches, protected rest areas, water fountains, rest rooms, news stands, escalators.

ATTRACTIVENESS--This factor refers to certain physical attributes of a pathway and its surrounding environment (landscape elements and buildings). To what extent is the pathway under consideration aesthetically appealing, interesting, well-organized, well-maintained, etc. In assessing this factor you might ask yourself if it is a place you would be willing to go out of your way to experience.

COMFORT--This factor refers to your perception of physical and psychological comfort. Examples of elements causing physical discomfort might include: excessive street noise (from automobiles, trucks, machinery), excessive exposure to the elements (cold, hot, snow, rain, wind), long stairways, very crowded conditions, steep hills, or uneven walking surfaces. Examples of pathway features which might produce psychological discomfort include: crowded conditions or the presence of people quite different from yourself (in terms of socioeconomic status, ethnic origin, styles of behavior), or the potential for disturbing or threatening encounters with other people.

DISTANCE--Your perception of the distance you are required to walk from where you begin your trip to your destination.

IMPEDANCE--This factor includes certain elements you are likely to encounter which could delay your trip, such as signal lights, busy street crossings, stairways, turns, buildings or other obstructions, large crowds of people and other "bottle necks."

INFORMATION--You might be inclined to select a pathway familiar to you to avoid the risk of getting lost, in spite of the possibility of favorable features on alternate routes. To what extent do you select a pathway based on your knowledge of the downtown area generally and of alternate walking routes in particular.

SAFETY--This factor refers to your perception of the safety hazards you might encounter along various pathways through the downtown area. Threats to your safety might include the possibility of being struck by automobiles or other vehicles when crossing intersections, dangerous stairways, machinery.

TIME--This factor simply refers to the time you think it would take you to walk from where you begin the trip to your destination.

OTHER--This refers to any other features, not included in the above factors, which might influence your pathway choice (it may be that no others exist).

The comfort factor was presented as two separate items: physical comfort and psychological comfort. Prior to each rating of importance, a brief definition of the factor was presented. This format allowed us to ascertain the attitudinal importance of each of the above factors across three separate and distinct types of uses (trip purposes).

During each separate trip, the amenities question was followed by asking the respondent to rank order in terms of importance the following six amenities: benches, shaded rest areas, rest rooms, news stands, water fountains, and others. This allowed us to investigate which amenities were of the most importance to the respondents.

Finally, we felt that convergent validity could be obtained by going beyond just an attitude score for each factor considered separately. Therefore, we asked each respondent to consider (for each scenario) all the factors together so that we could obtain data on the trade-offs involved when making a choice. The method used was to present all ten factors (physical and psychological comfort combined) and ask the respondent to rank order them in order of their importance for affecting his/her use of the pathway. By combining these data with the attitude data, a valid weighting of the importance of each factor could be obtained.

Respondents. The respondents were 132 men and women, ranging in age from 19 to 44. There were 79 females and 53 males; 45 came from cities of over 50,000 population and 87 came from cities of less than 50,000 population.

Results and Discussion

The mean attitude scores for the 11 factors (physical and psychological comfort treated separately) are presented in Table 8-1. A repeated measures analysis of variance was computed for each factor. As can be seen from the table, there was a significant within subjects effect for every factor except safety. That is, the respondent's scores for any factor (except safety) differed significantly across the three trips.

An examination of Table 8-1 reveals that safety was rated as being moderately important for all three trips. It is interesting to note some of the changes across trips. For example, attractiveness was rated as being very important for the social/recreational trip, moderately important for the shopping trip, and only slightly above neutral for the work trip. Similarly, time was rated as being very important for the work trip, moderately important for the shopping trip, and unimportant for the social/recreational trip. Other results of note include amenities being important for the social/recreational trip, less important for the shopping trip, and unimportant for the work trip; and impedance being important for the work trip, slightly less important for the shopping trip, and almost neutral for the social/recreational trip. Finally, when the respondents supplied other factors, they were uniformly rated as being unimportant.

These results indicate that our respondents were clearly able to differentiate among the factors, and apply them appropriately to the various trips.

TABLE 8-1. MEAN ATTITUDE SCORES

Factor	Work Trip	Social/ Recreational	Shopping
Accessibility*	2.42	3.03	1.79
Amenities*	4.01	2.11	2.95
Attractiveness*	3.21	1.89	2.96
Physical Comfort*	2.55	2.05	2.97
Psychological Comfort*	2.49	1.99	2.33
Distance*	2.26	4.44	2.43
Impedance*	2.33	3.61	2.64
Information*	2.62	3.89	2.55
Safety	2.64	2.71	2.42
Time*	1.70	4.41	2.51
Other*	5.74	5.99	6.28

*p .01

The results of the rank ordering of amenities are presented in Table 8-2. As can be seen from the table, the mean ordering of desired amenities also varied according to the nature of the trip. However, there was clearly not as much difference among the trips here as there was on the 11 factors. The most interesting finding is that shade was considered the most important amenity for the social/recreational trip, but dropped markedly for the shopping and work trips.

The mean rank ordering of the 10 factors (physical and psychological comfort combined) for the three trips are presented in Table 8-3. A repeated measures analysis-of-variance was computed, and there was a significant within subjects effect for all the factors except information and others. That is, a respondent's ranking of a factor varied according to the trip. An analysis of the table reveals, for example, that attractiveness was ranked highly (first in importance) for the social/recreational trip, but fell to near the bottom (seventh) for both the work and shopping trips. Similarly, time was ranked first for the work trip, fell to fourth for the shopping trip, and all the way to ninth for the social/recreational trip.

Again, these results indicate that the respondents were able to meaningfully apply the factors when rank order ing their importance for choosing a pathway for the various trips. In order to use these rank orderings in conjunction with the attitude score for each factor to derive a weighting of importance for the factors, the relationship among the factors and the rank-orderings needed to be assessed.

TABLE 8-2. MEAN RANK ORDER OF AMENITIES

Amenity	Work Trip (Rank)	Social/ Recreation (Rank)	Shopping (Rank)
Benches	3.95(5)	2.90(4)	2.81(3)
Shade	3.31(3)	2.45(1)	3.40(4)
Restrooms	2.42(1)	2.58(3)	1.92(1)
Newsstands	3.47(4)	4.64(5)	4.41(5)
Water Fountains	2.60(2)	2.55(2)	2.67(2)
Others	5.06(6)	5.36(6)	5.38(6)

TABLE 8-3. MEAN RANK ORDER OF FACTORS

Amenity	Work Trip (Rank)	Social/ Recreation (Rank)	Shopping (Rank)
Accessibility*	3.96(3)	4.18(3)	2.94(1)
Amenities*	7.04(9)	4.38(4)	5.61(6)
Attractiveness*	6.17(7)	2.65(1)	5.75(7)
Comfort*	5.29(5)	3.30(2)	4.08(2)
Distance*	3.27(2)	6.33(7)	4.17(3)
Impedance*	5.83(6)	6.36(8)	6.28(9)
Information	6.36(8)	6.26(6)	5.84(8)
Safety*	4.97(4)	4.76(5)	5.45(5)
Time*	3.04(1)	7.33(9)	5.36(4)
Others	8.55(10)	8.97(10)	9.15(10)

*$p < .01$

Tables 8-4, 8-5, and 8-6 contain the inter-attitude correlations for the 11 factors over the work, social/recreational, and shopping trips respectively. As can be seen from the tables, there are numerous significant correlations. Overall there are several interesting patterns. For example, for all three trips there was a significant negative correlation of time and attractiveness. As time increased in importance, attractiveness decreased, and vice versa. Not surprisingly, the other factor yielded very few significant correlations with the other factors. Finally, the physical comfort and psychological comfort factors often correlated significantly with different factors, justifying our decision to separate the overall comfort factor into these two components.

TABLE 8-4

Correlations Among Attitudes: Work Trip

	Accessibility	Amenities	Attractiveness	Physical Comfort	Psychological Comfort	Distance	Impedance	Information	Safety	Time
Accessibility										
Amenities	.184*									
Attractiveness	.226**	.448**								
Physical Comfort	.109	.104	.374**							
Psychological Comfort	.171*	.223**	.295**	.371**						
Distance	.066	-.081	-.264**	-.072	-.059					
Impedance	.214**	-.117	.036	-.029	.123	.146*				
Information	.121	.008	.010	.070	-.035	.126	.206**			
Safety	.165*	.113	.290**	.213**	.026**	.054	.295**	.191**		
Time	.213**	-.109	-.194**	-.074	.075	.478**	.232**	.121	.111	
Other	.036	.084	.192**	-.029	.044	.020	-.102	-.011	.074	.075

*$p < .05$

**$p < .01$

TABLE 8-5

Correlations Among Attitudes: Social Recreational

	Accessibility	Amenities	Attractiveness	Physical Comfort	Psychological Comfort	Distance	Impedance	Information	Safety	Time
Accessibility										
Amenities	.166*									
Attractiveness	-.022	.485**								
Physical Comfort	.096	.336	.381**							
Psychological Comfort	.036	.273**	.448**	.534**						
Distance	.293**	-.219**	-.230**	.009	.015					
Impedance	-.047	-.058	.008	.092	.256	.373**				
Information	.237**	-.025	-.143*	.055	-.191**	.480**	.210**			
Safety	.151*	.155*	.317**	.482**	.391**	.208**	.373**	.165*		
Time	.311**	-.124	-.230**	.014	-.063	.703**	.283**	.569**	.182*	
Other	-.091	-.062	.053	-.055	-.091	-.114	-.027	-.013	-.006	-.096

*p < .05

**p < .01

TABLE 8-6

Correlations Among Attitudes: Shopping

	Accessibility	Amenities	Attractiveness	Physical Comfort	Psychological Comfort	Distance	Impedance	Information	Safety	Time
Accessibility										
Amenities	.019									
Attractiveness	-.000	.600**								
Physical Comfort	.264**	.305**	.335**							
Psychological Comfort	.160*	.172*	.107	.392**						
Distance	.298**	-.024	.026	.104	.201*					
Impedance	.249**	-.191**	-.106	.043	.249**	.506**				
Information	.289**	-.050	.012	.090	.031	.178**	.395**			
Safety	.128	.020	.102	.169*	.198*	.215**	.283**	.219**		
Time	.321**	-.269**	-.124	.043	.009	.505**	.580**	.439**	.188**	
Other	-.052	-.019	-.004	.068	-.064	-.042	.070	.142*	-.141*	.065

*$p < .05$

**$p < .01$

More important than the above correlations is the correlations among the attitudes toward the factors and the rank ordering of those factors. Those correlations are presented in Tables 8-7, 8-8, and 8-9 (the work, social/recreational, and shopping trips, respectively). These correlations represent how the importance of a factor (attitudinal) was related to the relative importance of that factor (and the others) when it was rank ordered. Thus from Table 8-7 we can see that the importance rating of accessibility for the work trip correlated highly significantly with the rank ordering of accessibility. Similarly, the same was true for all of the other factors on the work trip. Note that the physical and psychological comfort factors are correlated with the rank ordering of the overall comfort factor.

The same is true for Table 8-8 (social/recreational trip) with one exception. The psychological comfort factor failed to correlate significantly with the rank ordering of the comfort factor. For Table 8-9 (shopping trip) all the factors correlated significantly with the rank ordering of the same factor.

Thus, convergent validation is achieved indicating that the attitudinal rating of importance of the factors is highly correlated with the same factor when it is considered in competition (in a rank-order sense) with all other factors. Therefore, the attitudinal scores provide a supportable measure of the importance to pedestrians of each of these pathway factors or attributes.

The following procedure was used to convert the attitudinal scores shown in Tables 8-7, 8-8 and 8-9:

(1) The attitude score was reversed so that 1 = least important and 7 = most important resulting in a set of A-scores for each trip purpose;

(2) The A-scores were converted to Z-scores by expressing each A-score, within a trip purpose category, in terms of its deviation from the mean in units of the standard deviation;

(3) The Z-scores were then weighted to obtain a set of W-scores using a weight of 1 for -3 standard deviations (very unimportant), a weight of 2 for 0 standard deviations (neutral) and a weight of 4 for +3 standard deviations (very important). This had the effect of making "neutral" twice as important as "very unimportant", and "very important" twice as important as "neutral" or four times as important as "very unimportant",

(4) Finally, all W-scores were expressed relative to the score for time, which is the nominal measure of perceived pathway impedance, to obtain a score denoted simply as W.

TABLE 8-7

Correlations Of Attitudes And Rankings: Work Trip

	Rank - Accessibility	Rank - Amenities	Rank - Attractiveness	Rank - Comfort	Rank - Distance	Rank - Impedance	Rank - Information	Rank - Safety	Rank - Time	Rank - Others
Accessibility	.407**	.000	-.120	-.202**	-.028	-.061	-.143*	.042	.123	.054
Amenities	-.034	.268**	.324**	.169*	-.170*	-.294**	-.259**	.031	-.120	.041
Attractive-ness	.044	.056	.440**	.167*	-.313**	-.187*	-.269**	.122	-.300**	.192*
Physical Comfort	.012	-.007	.088	.374**	-.149*	-.152*	.053	.042	-.217**	-.040
Psychological Comfort	.011	-.031	-.011	.199	-.177*	-.081	-.095	.140*	-.061	.000
Distance	-.131	-.262**	-.405**	-.171*	.580**	.036	.063	-.107	.431**	-.023
Impedence	.056	-.149*	-.244**	-.263**	.064	.366**	-.022	.128	.154*	-.081
Information	.054	-.112	-.262**	-.196*	-.091	.016	.368**	.081	.131	.072
Safety	.000	-.129	-.053	-.081	-.101	-.036	-.023	.452**	-.040	.029
Time	.004	-.192**	-.416**	-.407*	.214**	.056	-.029	.014	.596**	.131
Others	-.139	-.317**	-.022	-.031	-.058	-.092	-.190**	.047	-.014	.727**

*p < .05

**p < .01

TABLE 8-8

Correlations Of Attitudes And Rankings: Social/Recreational

	Rank - Accessibility	Rank - Amenities	Rank - Attractiveness	Rank - Comfort	Rank - Distance	Rank - Impedance	Rank - Information	Rank - Safety	Rank - Time	Rank - Others
Accessibility	.432**	.013	-.233**	-.172*	.213**	-.200**	-.121	.032	.194**	-.156*
Amenities	.054	.344**	.246**	.119	-.324**	-.199**	-.042	.123	-.239**	-.051
Attractive-ness	-.005	.228**	.517**	.128	-.324**	.041	-.144*	.157*	-.422**	-.010
Physical Comfort	-.003	.111	.135	.262**	-.143*	-.076	-.054	.122	-.191**	-.121
Psychological Comfort	-.034	.060	.133	.103	-.081	-.008	-.072	.128	-.222**	-.047
Distance	.043	-.192**	-.364**	-.209**	.526**	-.136	-.059	-.039	.454**	-.075
Impedance	-.092	-.022	-.118	-.156*	.092	.308**	-.105	-.003	.132	-.056
Information	.103	-.185*	-.333**	.143*	.263**	.100	.254**	-.012	.271**	-.135
Safety	-.115	-.114	.043	-.036	.003	-.003	-.034	.496**	-.055	-.150*
Time	.197**	-.283**	-.435**	-.291**	.511**	-.258**	.052	-.137	.591**	-.021
Others	-.019	-.152*	-.069	-.117	-.044	.035	.009	-.053	-.051	.521**

*$p < .05$
**$p < .01$

TABLE 8-9

Correlations Of Attitudes And Rankings: Shopping Trips

	Rank - Accessibility	Rank - Amenities	Rank - Attractiveness	Rank - Comfort	Rank - Distance	Rank - Impedance	Rank - Information	Rank - Safety	Rank - Time	Rank Others
Accessibility	.347**	-.005	-.285**	-.205**	.053	-.043	.099	-.141*	.071	.019
Amenities	.025	.519**	.336**	-.171*	-.324**	-.253**	-.024	.011	-.362**	-.179*
Attractive-ness	-.018	.218**	.537**	.099	-.280**	-.168*	.008	-.001	-.357**	-.123
Physical Comfort	.018	.177*	.116	.287**	-.222**	-.193**	.035	-.010	-.216**	-.003
Psychological Comfort	.079	.154*	-.120	.185*	-.007	-.033	-.066	-.058	-.098	-.038
Distance	.021	-.200**	-.336**	-.228**	.588**	-.081	-.087	-.124	.382**	-.030
Impedance	-.074	-.332**	-.291**	-.253**	.368**	.136*	-.038	-.038	.326**	.119
Information	-.113	-.272**	-.239**	-.119	.146*	-.027	.477**	-.131	.132	.120
Safety	-.148*	-.187*	-.072	-.039	.051	-.037	.010	.417**	.016	.087
Time	-.078	-.317**	-.365**	-.273**	.448**	.066	.000	-.171*	.483**	.189*
Others	-.076	-.014	.099	-.007	-.087	-.188*	-.042	-.117	-.168	.494**

*$p < .05$
**$p < .01$

The results of this effort are shown in Tables 8-10, 8-11 and 8-12.

The rel-scores are used in the following manner:

(1) Pathway attribute scores are obtained by assigning rating factors, in a scale of 0 to 10 for each attribute -

R_{ik} = pathway i weighting factor for attribute k;

(2) The rating factors are modified to obtain the pathway attribute scores -

S_{ik} = pathway i score for attribute k

$$= \frac{R_{ik} - 5}{10};$$

(3) The S_{ik} scores are then weighted using the W_{jk} = W for trip purpose j and attribute k, so that

$W_{jk} * S_{ik}$ = weighted attribute score for attribute k of pathway i for trip purpose j.

(4) Finally, the weighted scores are scaled by multiplying by a constant C = 0.143,

$$C * W_{jk} * S_{ik}$$

The $C * W_{jk} * S_{ik}$ are tabulated, and their use described, under Task 6 of the Procedures Manual.

Attribute	A-Score	Z-Score	W-Score	W
Accessibility	5.58	0.43	2.21	0.78
Amenities	3.99	-1.95	1.27	0.45
Attractiveness	4.79	-0.76	1.68	0.59
Physical Comfort	5.45	0.23	2.11	0.75
Psychological Comfort	5.51	0.32	2.15	0.76
Information	5.38	0.13	2.06	0.73
Safety	5.36	0.10	2.05	0.72
Time	6.30	1.50	2.83	
Mean	5.30			
Standard Deviation	0.67			

TABLE 8-10

DETERMINATION OF ATTRIBUTE WEIGHTS
WORK TRIP

Attribute	A-Score	Z-Score	W-Score	W
Accessibility	6.21	1.90	3.10	1.50
Amenities	5.05	-0.96	1.60	0.78
Attractiveness	5.04	-0.99	1.59	0.77
Physical Comfort	5.03	-1.01	1.58	0.77
Psychological Comfort	5.67	0.57	2.28	1.11
Information	5.45	0.02	2.01	0.98
Safety	5.58	0.35	2.17	1.05
Time	5.49	0.12	2.06	
Mean	5.44			
Standard Deviation	0.41			

TABLE 8-11

DETERMINATION OF ATTRIBUTE WEIGHTS
SHOPPING TRIPS

Attribute	A-Score	Z-Score	W-Score	W
Accessibility	4.97	-0.28	1.87	1.40
Amenities	5.89	0.68	2.34	1.75
Attractiveness	6.11	0.91	2.47	1.84
Physical Comfort	5.95	0.75	2.38	1.78
Psychological Comfort	6.01	0.81	2.41	1.80
Information	4.11	-1.19	1.52	1.13
Safety	5.29	0.05	2.02	1.51
Time	3.59	-1.73	1.34	
Mean	5.24			
Standard Deviation	0.95			

TABLE 8-12

DETERMINATION OF ATTRIBUTE WEIGHTS
SOCIAL/RECREATION TRIPS

APPENDIX

PATHWAY CHOICE AND BEHAVIOR QUESTIONNAIRE

DECEMBER 1976

NOTE: This was the questionnaire which was finally developed. It was administered to 132 persons as described in the analysis.

Many cities throughout the U.S. are attempting to make their downtown areas better places in which to work and live. One aspect of this effort is to provide pedestrians with better environments for their walking trips. To do this requires that we have a better understanding of the features people look for when they choose a particular walking route. Your thoughtful response to our questions will greatly assist this understanding.

FACTORS INFLUENCING PATHWAY CHOICE

We are interested in why you make the choices you do when walking. There are no doubt a number of things which influence your choice of routes or pathways, and we want to gain a better understanding of these influences. In order to do so, we would like you to consider the following types of potential influences on pathway choice.

ACCESSIBILITY--How accessible are the various places you may want to reach to your major location (work or home), such as, shops, department stores, friends, parks, restaurants?

AMENITIES--As you contemplate the selection of a route you may consider various amenities, such as benches, protected rest areas, water fountains, rest rooms, news stands, escalators.

ATTRACTIVENESS--This factor refers to certain physical attributes of a pathway and its surrounding environment (landscape elements and buildings). To what extent is the pathway under consideration aesthetically appealing, interesting, well-organized, well-maintained, etc. In assessing this factor you might ask yourself if it is a place you would be willing to go out of your way to experience.

COMFORT--This factor refers to your perception of physical and psychological comfort. Examples of elements causing physical discomfort might include: excessive street noise (from automobiles, trucks, machinery), excessive exposure to the elements (cold, hot, snow, rain, wind), long stairways, very crowded conditions, steep hills, or uneven walking surfaces. Examples of pathway features which might produce psychological discomfort include: crowded conditions or the presence of people quite different from yourself (in terms of socioeconomic status, ethnic origin, styles of behavior), or the potential for disturbing or threatening encounters with other people.

DISTANCE--Your perception of the distance you are required to walk from where you begin your trip to your destination.

IMPEDANCE--This factor includes certain elements you are likely to encounter which could delay your trip, such as signal lights, busy street crossing, stairways, turns, buildings or other obstructions large crowds of people and other "bottle necks".

INFORMATION--You might be inclined to select a pathway familiar to you to avoid the risk of getting lost, in spite of the possibility of favorable features on alternate routes. To what extent do you select a pathway based on your knowledge of the downtown area generally and of alternate walking routes in particular.

SAFETY--This factor refers to your perception of the safety hazards you might encounter along various pathways through the downtown area. Threats to your safety might include the possibility of being struck by automobiles or other vehicles when crossing intersections, dangerous stairways, machinery.

TIME--This factor simply refers to the time you think it would take you to walk from where you begin the trip to your destination.

OTHER--This refers to any other features, not included in the above factors, which might influence your pathway choice (it may be that no others exist).

It has probably occurred to you that several of the factors overlap. For example, the time it might take you to walk to your destination depends in great part on the distance and the number and type of impedances (street crossings, turns, obstructions) you encounter. However, try in your responses to consider each of the factors separately.

Also, it is clear that no one pathway is ideal with respect to these factors. That is, one of the available pathways may be the most aesthetically appealing to you may be very well maintained and may bring you into contact with people with whom you are comfortable, but takes you considerably out of your way. Another possible route may be quite direct (in terms of distance) but somewhat unattractive and require you to climb several sets of stairs. Yet another available pathway might provide a quite direct, attractive, unimpeded route through the downtown area, but you don't know that part of town (the "information" factor) and could get lost or otherwise be disappointed in your selection.

Finally, we come to trip purpose. The factors listed above may differ in relative importance, depending on the type of trip being considered. For instance, if you are walking to work you may assign different importance to the factors than you would if you were on a shopping trip. Likewise, you might consider the factors differently if the purpose of your trip is recreational.

As you must begin to realize, the seemingly simple act of choosing a pathway in a city can, in fact, be quite complicated when you come to think about it; this is what we would like for you to do--think about the above factors in terms of making a pathway selection. Specifically, we would like you to think about the influence of each of these factors on your decision to take one route rather than another. We are very interested to learn how you choose a particular pathway.

WORK TRIP

We will begin by asking you to imagine that you have just taken a new position in a firm located in the downtown area of a city. You have decided that although the firm is located a considerable distance away from your residence/the bus terminal where you arrive from the suburbs/the only available or inexpensive parking facility, it is feasible for you to walk to and from work. Thus you are about to select a route or pathway for your trip. How would you evaluate the factors we have been discussing in your selection?

Please circle the numer which best represents your answer to each question.

ACCESSIBILITY: Work Trip

Note: Accessibility refer to the ease with which you can pass to and from or make use of various places you may want to reach en route to your major destination.

a) How important is accessibility to you in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

AMENITIES: Work Trip

Note: Amenities refer to various features which might add to your pleasure or convenience such as benches, water fountains, rest rooms, shaded rest areas.

a) How important is the inclusion of various amenities to you in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

b) Please rank the following amenities in terms of their importance to your pathway choice. Assign a "1" to the most important, a "2" to the second most important, etc.

_____ benches

_____ shaded rest areas

_____ rest rooms

_____ news stands

_____ water fountains

_____ other

ATTRACTIVENESS: Work Trip

Note: Refers to the aesthetic appeal, interestingness, and maintenance of the pathway environment.

a) How important is the physical attractiveness of a pathway to you in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

COMFORT (physical and psychological): Work Trip

Physical Comfort: Work Trip

Note: Refers to bodily comfort, for example, hot, cold, wind, noise.

a) How important is physical comfort to you in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

Psychological Comfort: Work Trip

Note: Refers to psychological comfort, for example, feelings of crowdedness, presence of unfamiliar types of people; also the possibility for disturbing or threatening encounters with other people.

a) How important is psychological comfort to you in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

DISTANCE: Work Trip

Note: Refers to your perception of the distance you would walk on a pathway.

a) How important to you is the distance you must walk to reach your destination in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

IMPEDANCE: Work Trip

Note: Refers to elements encountered which delay your trip, for example, busy street crossings, signal lights, turns, stairways, "bottlenecks" and other obstructions.

a) How important to you are the number of impedances on a pathway in your choice and use of a particular pathway (even though the distance is no greater than that of other pathways)?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

INFORMATION: Work Trip

Note: Refers to your knowledge of the downtown area generally, and of specific alternate routes to your destination (that is, are you inclined to select a pathway which is unfamiliar to you)?

a) How important to you is your knowledge of alternate routes to your destination in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

SAFETY: Work Trip

Note: Refers to your perception of personal safety with regard to objects (for example, from automobiles at intersections without signals to hazardous stairways).

a) How important to you is your perception of safety in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

TIME: Work Trip

Note: Refers to your perception of the time it takes to reach your destination (that is, work).

a) How important to you is the time you think it will take to get your destination in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

OTHER: Work Trip

Note: Refers to some factor not covered by the others which you think is important in your pathway choice.

a) Do you think there is another factor which influences your pathway choice?

b) Describe briefly the additional factor:

c) How important do you consider this factor in your choice and use of a particular pathway?

1	2	3	4	5	6	7
Very important			Neutral			Very unimportant

We would like to ask you to give us your final evaluation with regard to your work trip:

The ten (10) factors we have been asking you to evaluate are listed below. Using #1 for the most important factor affecting your use of a pathway, and #10 for the least important factor in your use of a pathway to your work destination, please rank order these factors (1 to 10) by assigning a number between 10 and 10 to each factor in the space to the left.

WORK TRIP

RANK ORDER

_____ Accessibility

_____ Amenities

_____ Attractiveness

_____ Comfort

_____ Distance

_____ Impedance

_____ Information

_____ Safety

_____ Time

_____ Other

SOCIAL/RECREATIONAL TRIP

Now we would like you to evaluate the same factors as though you were selecting a pathway through the downtown area for social or recreational purposes. Although the questions are the same, your responses may differ due to the nature of this kind of walking trip.

SHOPPING TRIP

Now we would like for you to evaluate the same factors as though you were selecting a pathway through the downtown area for the purposes of shopping at various establishments. Although the questions are the same, your responses may differ due to the nature of this kind of walking trip.

SUPPLEMENT 9

PEDESTRIAN TRIP MAKING PROPENSITY CONSIDERATIONS

1. Introduction

This Supplement describes pedestrian trip making attentuation data, which are used as the basis for developing inter-centroid friction factors. Where primary data were described on the basis of distance, the equivalence of one minute equals 264 feet was used for conversion.

It should be recognized that, in theory the propensity to make a pedestrian trip of a given length begins to decrease immediately as trip time increases. However, most empirical data indicates that the probability increases slightly before beginning to decrease. This is caused by the spatial separation of centroids found in all urban centers. For example, if pedestrian trips to bus stops are being examined, and the nearest appropriate generators are located three minutes from the nearest bus stop, then no trips will be found to be shorter than three minutes. By examining the data, it would be concluded that the propensity to make a trip shorter than three minutes is zero, when in fact the data are influenced by the physical characteristics of the locality. This concept should be considered when the attentuation curves and friction factors are being applied. If necessary, curves can be modified to suit.

Tabulated values for the attenuation curves shown in Figure 9-1 are derived from empirical data collected at a range of sites. The values shown were obtained by averaging the individual curves.

Friction factor curves presented in the Procedures were obtained by plotting the frequency distribution derived from the intervals of the following cumulative distributions. For example, in the cumulative distribution for shopping trips, there is a 10% probability of a trip being between 3 and 4 minutes in length (80%-70%). Hence, a point on the friction factor curve at 3.5 minutes (3 to 4 minute average) was plotted as F(I,J) = 10. The resultant friction factor curves are smoothed from these data.

Probability of Pedestrian Trip of Time t or Greater

t	Shopping	Lunch	Long-Term Parking	Public Transit	All Transit Modes	Short-Term Parking
0	100	100	100	100	100	100
1	97	80	93	90	93	74
2	91	54	84	80	83	49
3	80	37	75	60	68	36
4	70	26	64	39	56	28
5	58	18	53	25	42	20
6	47	14	43	17	32	16
7	35	12	35	12	26	12
8	27	10	29	9	23	9
9	22	8	24	6		7
10	17	6	21	5		6
11	13	4	18	4		5
12	11	3	16			4
13		2	14	3		3
14		1	12			2
15		0	11	2		
16			9			
17			7			
18			5			
19			4	1		
20						

Figure 9-1

Pedestrian Trip Attenuation Data
By Trip Purpose

SUPPLEMENT 10

GUIDELINES ON DOING A PEDESTRIAN COUNT*

METHODOLOGY

A comprehensive pedestrian count, to determine the overall pedestrian traffic patterns for a multiplicity of purposes, should include all midblock points and intersections in the CBD core. Where manpower and funds are limited, the count may be confined to midblock locations alone or to principal pedestrian routes in the CBD core. More restricted pedestrian counts should be undertaken as follows: at intersections where pedestrian accidents exceed four a year or where pedestrian movement creates other traffic problems; at mid-block locations where heavy pedestrian volumes occur; or at areas or locations prescribed by the count's purpose.

To provide an accurate picture of pedestrian traffic, the distorting effects of abnormal seasonal and temporal conditions should be avoided. The count should not be conducted when unusually hot or cold weather keeps people off the streets or out of the CBD altogether. Holidays, special events involving parades and the like, or unusual disturbances such as fires and major accidents should also be avoided. The hours for the count are perhaps the crucial consideration. In all instances the count should fall between the hours of 6 a.m. and 7 p.m.; at a minimum, it should include the period from noon to 6 p.m., when peak volumes generally occur. While some counts have been taken for periods as short as six hours, nine to 12-hour counts will offer more accurate results, particularly where heavy pedestrian flows throughout the day can be expected.

The counting locations may be subject to additional distorting influences which should, if possible, be avoided; in any event, the distortions should be recorded by the counter. Street or sidewalk repairs and new construction will divert pedestrian traffic from normal routes, as will heavy activity at truck loading zones and delivery areas. Where a counting location falls between two nearby major pedestrian traffic generators -- large department stores, for example -- large numbers of pedestrians approaching and entering the generators will not be recorded. In such an instance it is necessary to relocate the count station or possibly to add a second.

While the precise manpower requirements for a counting station can only be fixed by a test count, Table 10-1 lists some guidelines.

*Excerpted from David Emmons, "The Pedestrian Count", Report No. 199, Aspo Planning Advisory Service, American Society of Planning Officials, Chicago, June 1965.

TABLE 10-1

Pedestrian Count Manpower Requirements

PEDESTRIAN COUNT MANPOWER REQUIREMENTS

Pedestrian Volume	Number of Counters Necessary	Manual Counting Devices Necessary*	Counting Capacity of Counter
MID-BLOCK COUNTS			
If peak hour pedestrian volumes rate is: less than 2,000 in both directions	1	2	Volume for each direction of flow
Greater than 2,000 but somewhat less than 5,000 in both directions	1	1	Total volume with no differentiation by direction of flow
Greater than 2,000 in both directions	2	1 per counter	Volume of 1 direction of flow per counter
Greater than 2,000 but less than 5,000 in 1 direction	1	1 (a tally being made for every 5 to 10 pedestrians)	Volume of 1 direction of flow
As high as 10,000 in 1 direction for short periods of time	1	1 (a tally being made for every 5 to 10 pedestrians)	Volume of 1 direction of flow
INTERSECTION COUNTS**			
If volume is: light and crosswalks are used alternately	1	1	Total volume in all 4 crosswalks
Moderate and crosswalks are used alternately	1	1 or 2	Separate or total volume in 2 crosswalks converging at count location
Greater than 2,000 pph in each crosswalk and crosswalks are used alternately	8 (2 for each crosswalk)	1 per counter	Volume for 1 direction of flow in 1 crosswalk per counter

*If pencils and tally sheets are used instead of manual counting devices, the counting capacity is reduced by approximately one-half.

**This refers to simple intersections with 4 crosswalks. Where intersections with more than 4 crosswalks are involved, more counters than listed may be required.

SOURCE: Manual of Traffic Engineering Studies, p. 92.

For midblock counts, a single counter should station himself on the building side of the sidewalk so as not to obstruct the flow of pedestrians. If two or more counters are required at a location, they should stand on the edge of the sidewalk that is most convenient for counting. In such cases, counting may be facilitated by dividing the sidewalk into lanes with chalkmarks. A counter using a mechanical counting device merely enters the cumulative totals on a half-hour or hourly basis onto a tally sheet and later transcribes the data on a summary sheet, subtracting one total from the next to find the actual count for each time period. (A sample summary sheet is shown in Figure 10-1.) If a pencil is used, the count is tabulated directly on the tally sheet and summarized later.

For intersection counts, a single counter should station himself at the inside of a corner offering a clear view of all crosswalks. If two counters are required at an intersection, they should stand on diagonally opposite corners. Table 10-2 indicates the appropriate division of counting responsibility for the most common types of intersections and numbers of counters. Data are recorded in the appropriate box on a special intersection field sheet (see Figure 10-2) and later entered and totaled on a summary sheet.

A half-hour -- occasionally a quarter-hour -- division for count tabulation is generally used for partial counts, while the hourly division is used for continuous counts. The latter is a complete enumeration, the counter remaining stationary throughout the count. In the former, which greatly reduces the personnel needed for an area-wide count, the counter records pedestrian traffic at one location for the first 15- or 30-minute interval of an hour, and then moves to another, nearby location for the second interval, returning to the first location at the end of the hour cycle. The process is repeated through the duration of the count. The total hourly traffic volume at each location can be approximated by multiplying the partial count data for each hour by the number of intervals in each hour cycle. However, a more accurate method of expanding the partial count involves the use of total count figures at locations with similar characteristics as the partial count locations. A recent pedestrian traffic survey of Salt Lake City describes the method:

> To expand the sample counts to an estimate for a full eight-hour day, a ratio was computed. This was done by using the counts taken at total count locations during the periods of the day which corresponded to the periods during which counts were taken at the sample locations. By adding together the counts taken during the matching periods and subtracting this figure from the sum of the all-day counts of the total count locations, a ratio was then calculated as a simple percentage. This ratio, when established, was then used to expand the counts taken at the sample locations to the equivalent of full-day counts.

TABLE 10-2

INTERSECTION COUNT INSTRUCTIONS

Type of Intersection	Number of Counters		
	2	4	8
Unsignalized	Each counter counts pedestrians to and from his corner in converging cross-walks and jaywalkers on one diagonal		
Signalized (pedestrians cross (alternately)		Each counter counts pedestrians to his corner in converg-ing crosswalks and jaywalkers to his corner	Each counter counts pedestrians to his corner in one cross-walk; every other one counts jaywalkers to his corner
Signalized (pedestrians cross (alternately)		Each counter counts pedestrians to and from his corner in one crosswalk and jaywalkers to his corner	Each counter counts pedestrians to his corner in one cross-walk; every other one counts jaywalkers to his corner

SOURCE: Manual of Traffic Engineering Studies, p. 93.

PRESENTATION OF DATA

The standard technique for presenting pedestrian count data is the statistical table. The example shown in Figure 10-3 lists for part of a day total pedestrian traffic on east-west streets in downtown Denver. For more refinement, a table may list the hourly or half-hourly volume totals for each count location, differentiating volumes by direction of flow. For comparative purposes, it is useful to rank the total volumes for each count location as a percent of the highest volume count location.

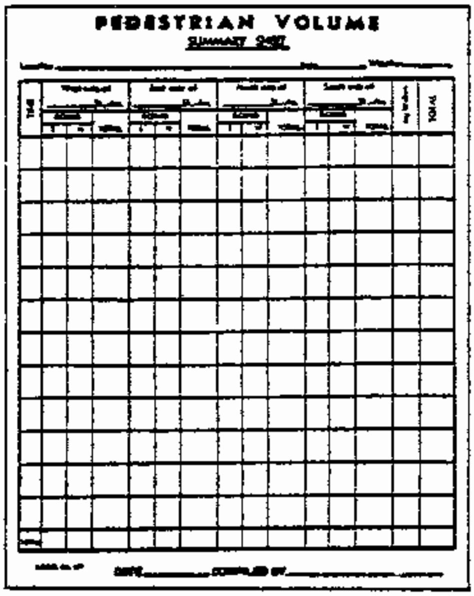
While graphs and maps cannot present count data with the precision of a statistical table, they allow for more vivid comparison and analysis. By representing volume and time on the vertical and horizontal coordinates of a graph, volume lines for one or more count locations can be plotted. As illustrated in Figure 10-4, the effect is to make the peak-hour pedestrian volumes for each of three count locations clearly visible. Where pedestrian counts have been taken over a number of years at various locations, graphic presentation of data facilites comparison between corresponding volume levels.

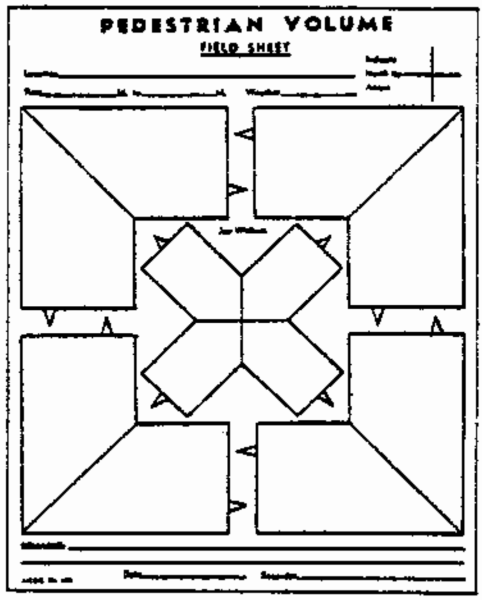
When pedestrian count data is diagrammed onto a street map, the effect, as shown in Figure 10-5, is a clear representation of pedestrian volume -- in this case at main intersections. Where midblock data are shown on a map, as seen in Figure 10-6, the overall pedestrian flow pattern is readily apparent. Another variation is to diagram the direction of pedestrian movement; in Figure 10-7, arrows are used to show the direction of predominant movement.

If land uses were shown on the maps in Figures 10-5, 10-6, and 10-7, then some insight could be obtained into the pedestrian-generating capacities of specific land uses. However, a more accurate understanding of the link between pedestrians and specific land uses requires more qualitative studies such as the pedestrian O & D survey.

CONCLUSION

If pedestrian planning is to maximize the mobility, safety, and pleasure of the pedestrian as he travels in the CBD, the characteristics of pedestrian movement must be known. To this end, the pedestrian count is a useful research aid, providing quantitative data on the volume, direction, and overall traffic pattern of pedestrians in the downtown. Its limitations suggest that other more sophisticated research techniques must be developed to provide a more complete understanding of pedestrian traffic. Nevertheless, with greater attention being directed to pedestrian needs in the CBD, the pedestrian count, with its numerous planning applications, should not be ignored.





SOURCE FOR FIGURES 1 AND 2: Manual of Traffic Engineering Studies (New York: Association of Casualty and Surety Companies, 1953), p. 94.

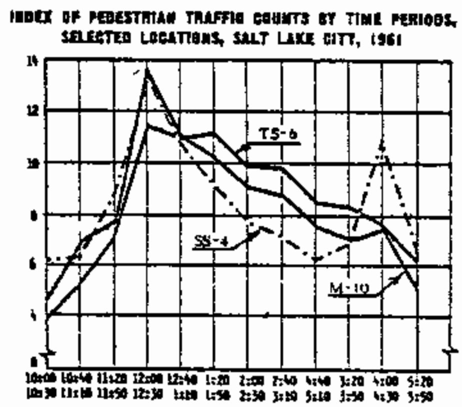
FIGURE 10-1

FIGURE 10-2

Pedestrian Traffic on East-West Streets in Downtown Denver, June, 1951
9:30 A. M.-12:00 Noon and 2:00 P. M.-4:00 P. M.

Street (both sides)	Number of Pedestrians Male	Female	Total	Per Cent of Total Count on East-West Streets Male	Female	Total
Larimer	9,054	1,407	10,461	5.5	0.9	6.4
Lawrence	5,229	4,046	9,275	3.2	2.5	5.7
Arapahoe	5,184	3,364	8,526	3.3	2.1	5.4
Curtis	13,482	9,623	23,105	8.2	5.9	14.1
Champa	11,336	10,912	22,248	6.9	6.7	13.6
Stout	12,182	9,765	21,947	7.5	6.0	13.5
California	10,717	8,222	18,939	6.6	5.0	11.6
Welton	9,378	4,595	13,973	5.8	2.8	8.6
Glenarm	7,704	5,035	12,739	4.7	3.1	7.8
Tremont	7,608	5,256	12,864	4.6	3.2	7.8
Court	3,867	2,167	6,034	2.4	1.3	3.7
Cleveland*	1,671	925	2,596	1.0	0.6	1.6
Cheyenne*	227	146	373	0.1	0.1	0.2
Total	97,532	64,943	162,475	59.6	40.4	100.0

*No count on south side between 15th Street and W. Colfax.
*North side only between Broadway and 16th Street.

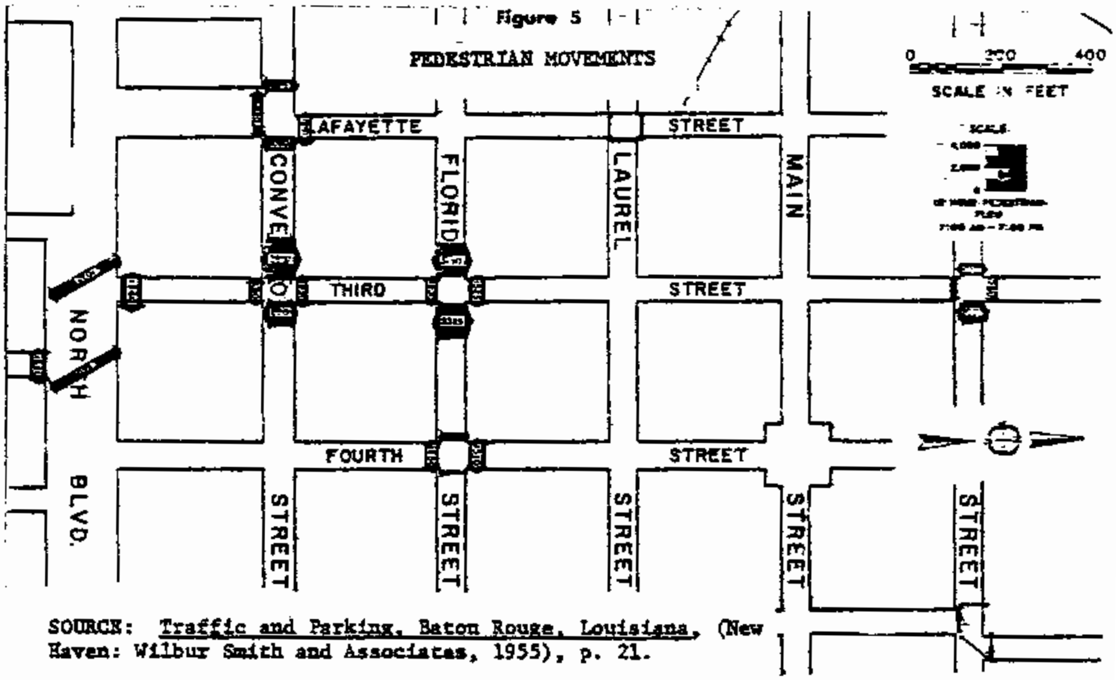


SOURCE FOR FIGURE 3: "Pedestrian Traffic in Downtown Denver," University of Denver Reports, August 1951, (Business Study No. 119), p. 3.

SOURCE FOR FIGURE 4: "Pedestrian Traffic Patterns in Salt Lake City," Utah Economic and Business Review, September, 1962, p. 4.

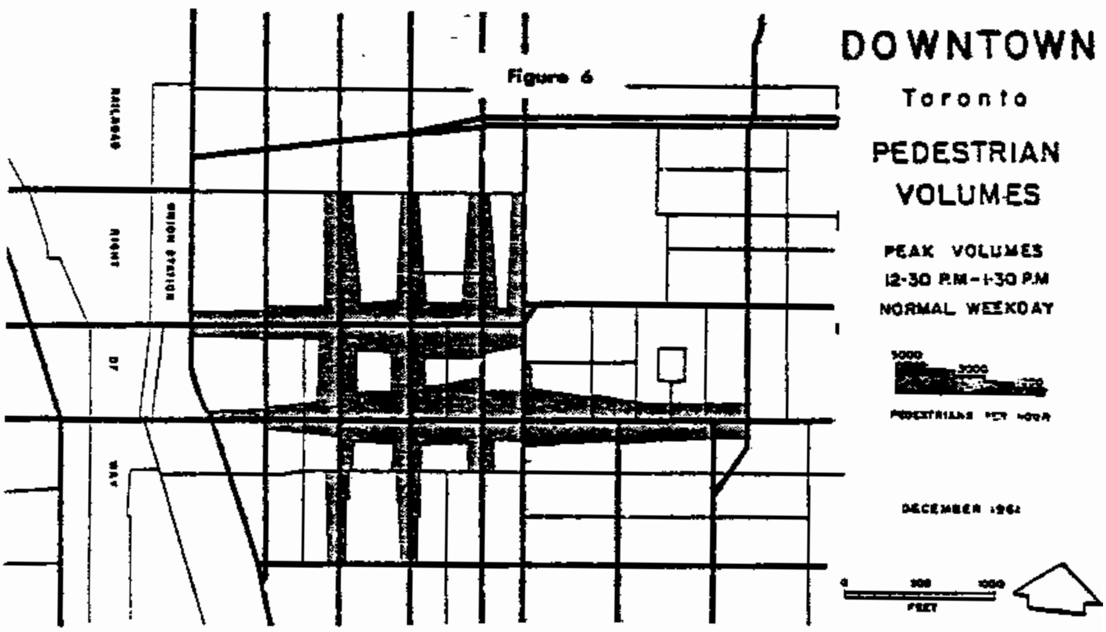
FIGURE 10-3

FIGURE 10-4



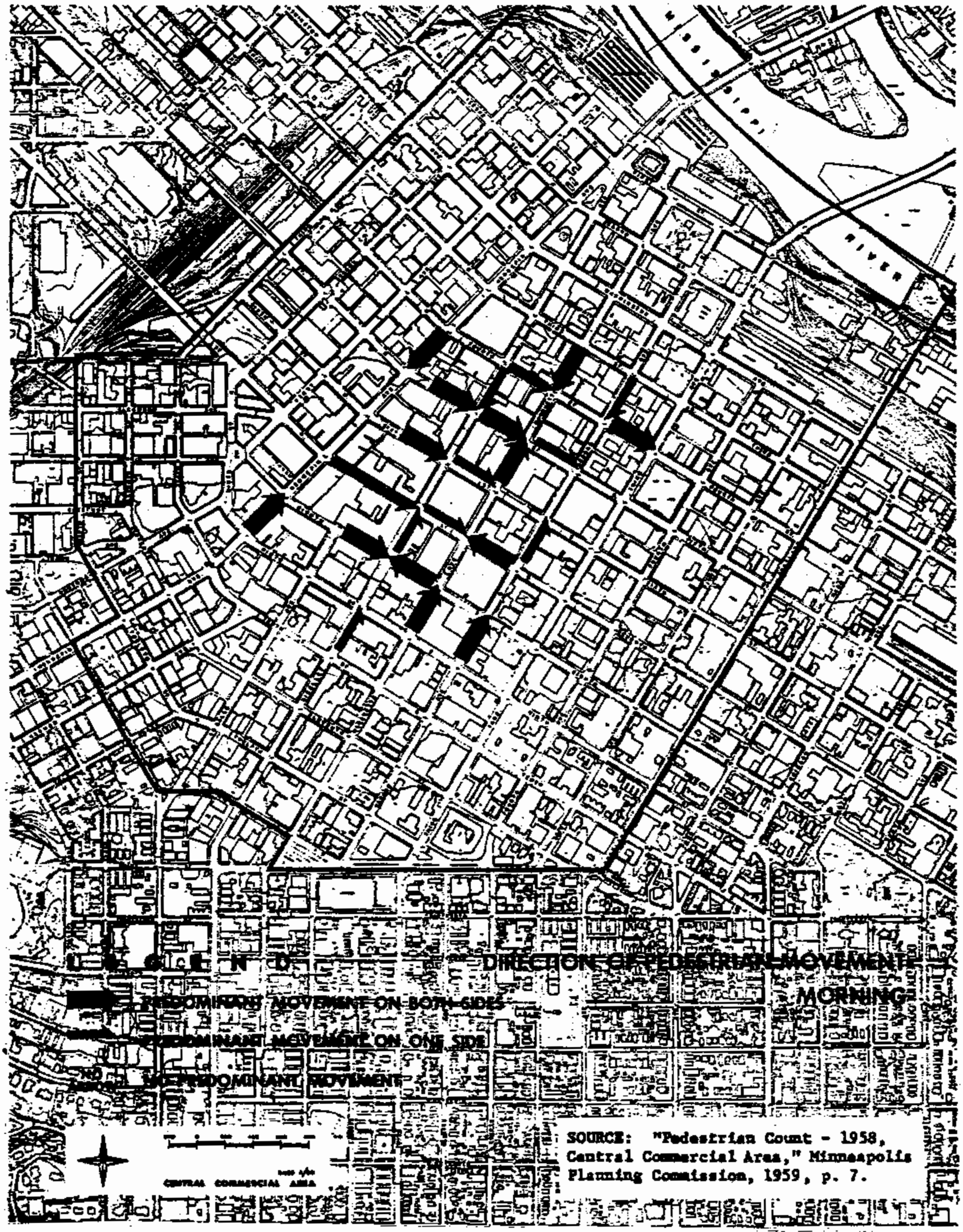
SOURCE: Traffic and Parking, Baton Rouge, Louisiana, (New Haven: Wilbur Smith and Associates, 1955), p. 21.

FIGURE 10-5



SOURCE: Downtown Planning District Appraisal, Toronto Planning Board, 1961, p. 10a.

FIGURE 10-6



SOURCE: "Pedestrian Count - 1958, Central Commercial Area," Minneapolis Planning Commission, 1959, p. 7.

FIGURE 10-7

SUPPLEMENT 11

EXAMPLES AND PROCEDURES FOR CALCULATING INTERSECTION AREA REQUIREMENTS

Part I. Illustrative Example of Calculation of Intersection Area Requirements.

Givens:

A sidewalk intersection has the following projected demand volumes and signal cycle:

Vertor V_A = 600 peds/15 minute peak period
Vector V_B = 450 peds/15 minute peak period
Condition 1 - Vector V_C = 300 peds/15 minute peak period
Condition 1 - Vector V_D = 150 peds/15 minute peak period
Condition 2 - Vector V_D = 300 peds/15 minute peak period
Condition 2 - Vector V_C = 150 peds/15 minute peak period

Total signal cycle (TS) = 80 seconds
Green light time/cycle for crosswalk C (TG_c) = 48 seconds
Green light time/cycle for crosswalk D (TG_d) = 32 seconds

(1) Initialize movement vectors (See Figures 11-1, 11-2)

(2) Adjust volumes,

V_A (5.33) = (600) (5.33) = 3198 peds/hr.

V_B (5.33) = (450) (5.33) = 2398 peds/hr.

Cond. 1-V_D (0.09) = 150 (0.09) = 13.5 (1)
Cond. 2-V_D (0.09) = 300 (0.09) = 27.0 (2)

Cond. 1-V_C (7.11) = 300 (7.11) = 2133 (1)
Cond. 2-V_C (11.03) = 150 (11.03) = 1655 (2)

(3) Compute EWW_s

For $(EWW)_A$ = 3198 = 9 ft.
For $(EWW)_B$ = 2398 = 8 ft.

Cond. 1 For $(EWW)_C$ = 2133 = 7 ft. (1)
Cond. 2 For $(EWW)_C$ = 1655 = 6 ft. (2)

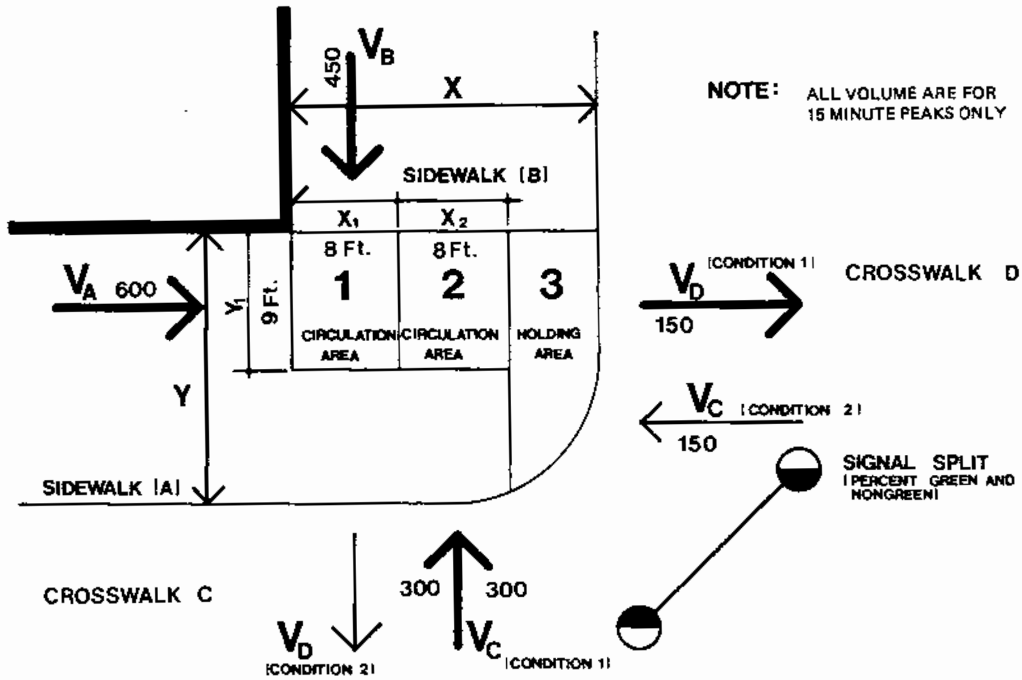


FIGURE 11-1

Area Required For Condition 1 Movement Vectors

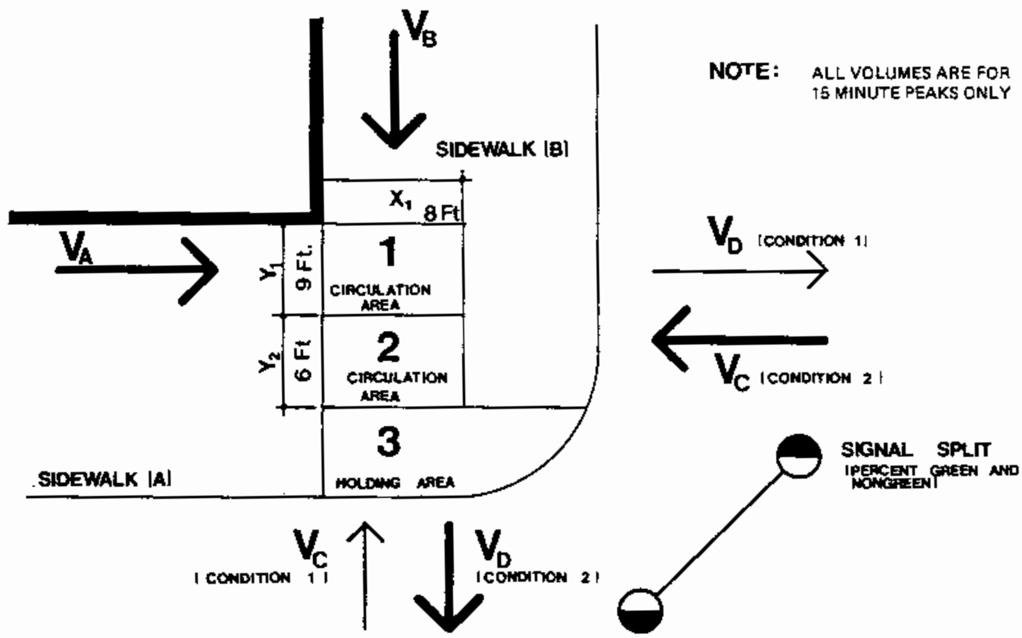


FIGURE 11-2

Area Required For Condition 2 Movement Vectors

(4) Compute holding area #3

Cond. 1 = $\frac{1}{12}$ (13.5) (48) = 54 sq. ft.

Cond. 2 = $\frac{1}{12}$ (27.0) (32) = 72 sq. ft.

(5) Compute area required for Condition 1.

AR = Area #1 + #2 + #3

AR = (9 8) + (7 9) + 54 sq. ft.

72 + 63 + 54 = 189 sq. ft.

For Condition 2,

AR = (9 8) + (8 6) + 72 sq. ft.

72 + 48 + 72 = 192 sq. ft.

(6) Compute available area

$$AA = 1.67 \ (x) \ (y) - .215r^2$$

Given that,

x = 12'
y = 14'
r = 12'

$$AA = (1.67) \ (12) \ (14) - .215 \ (12)^2$$

280.56 - 30.96 = 250 sq. ft.

(7) Compare (AA) to (AR)

For Cond. 1	250	189 + 18.9 = 208
	250	208
Cond. 2	250	212

Therefore, the intersection is adequate.

To evaluate crosswalk width,

(1) Compute the two directional volumes

V_1 = (300) + (300) = 600

V_2 = (150) + (150) = 300

(2) Compute the one minute crosswalk volume

$$V_{(ADJ)} = \frac{V}{15} \quad \frac{TS}{TG-3}$$

$$V_{1(ADJ)} = \frac{600}{15} \quad \frac{80}{(32-3)} = 110 \text{ PPM}$$

$$V_{2(ADJ)} = \frac{300}{15} \quad \frac{80}{(48-3)} = 36 \text{ PPM}$$

(3) Compute level of service

$$LS = \frac{V}{EWW}$$

For Crosswalk D $= \frac{36}{9} = 4$ PFM

Crosswalk C $= \frac{110}{8} = 14$ PFM

(4) Eval. level of service

For Crosswalk D 4 15 ....adequate.
For Crosswalk C 14 15 ....adequate.

Part II

Procedures For Computing Intersection Area Requirements for Standard Signal Phases

Definition of Intersection Area Requirements

The area required to avoid congestion resulting from cross trafficking and queuing at intersections is composed of two components; (see Figure 11-3, 11-4).

(1) Circulation Areas (#1 and #2)

a. Area #1 is the area required to allow pedestrians moving along sidewalk (A) and sidewalk (B) to merge and circulate through the intersection.

b. Area #2 is the area required to allow pedestrians moving across the street (C) into the sidewalk intersection.

2. Holding Area (#3). This is the area required for pedestrians to queue - waiting to cross during the walk signal interval (D).

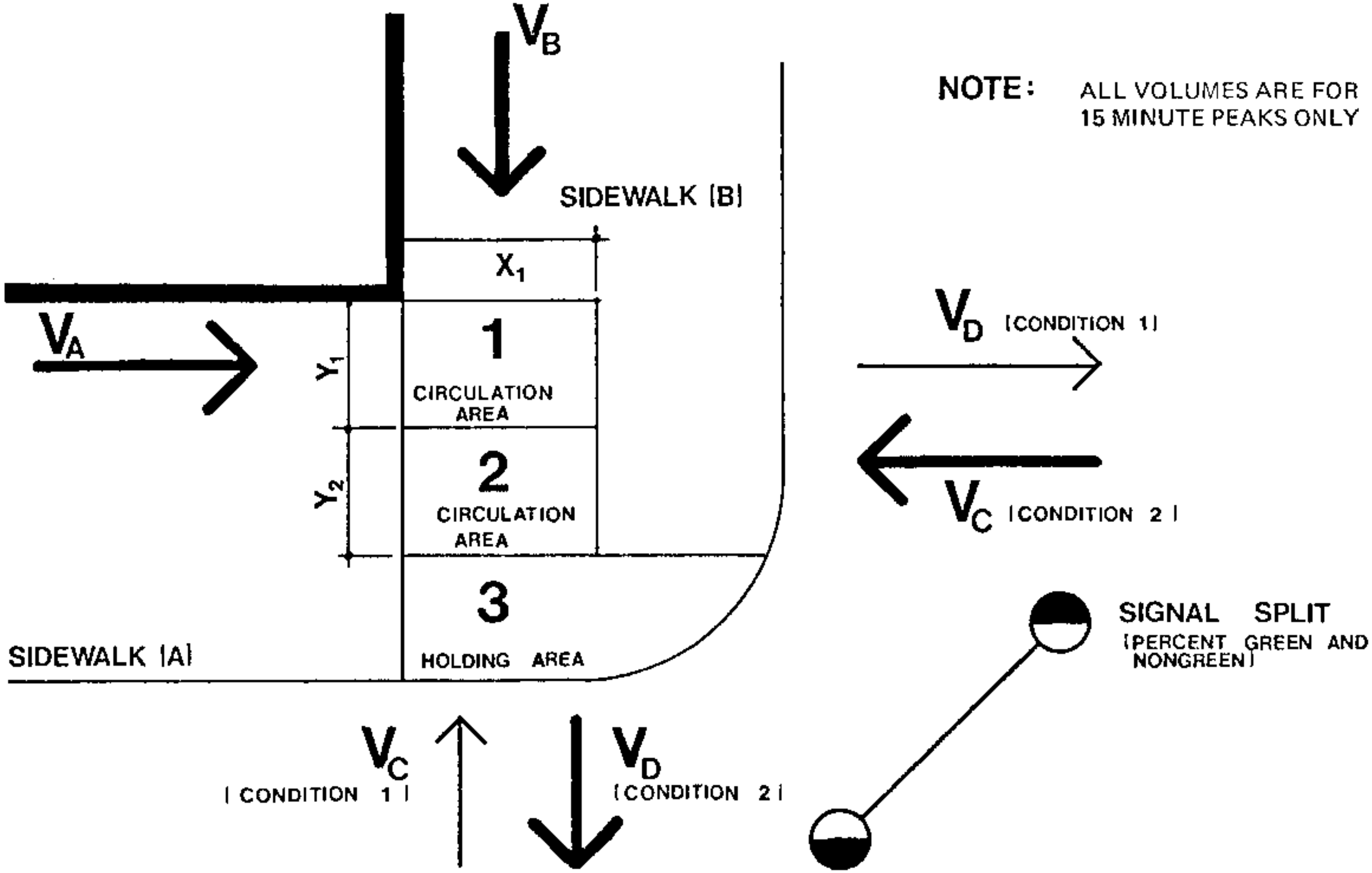


FIGURE 11-3

Area Required For Condition 2

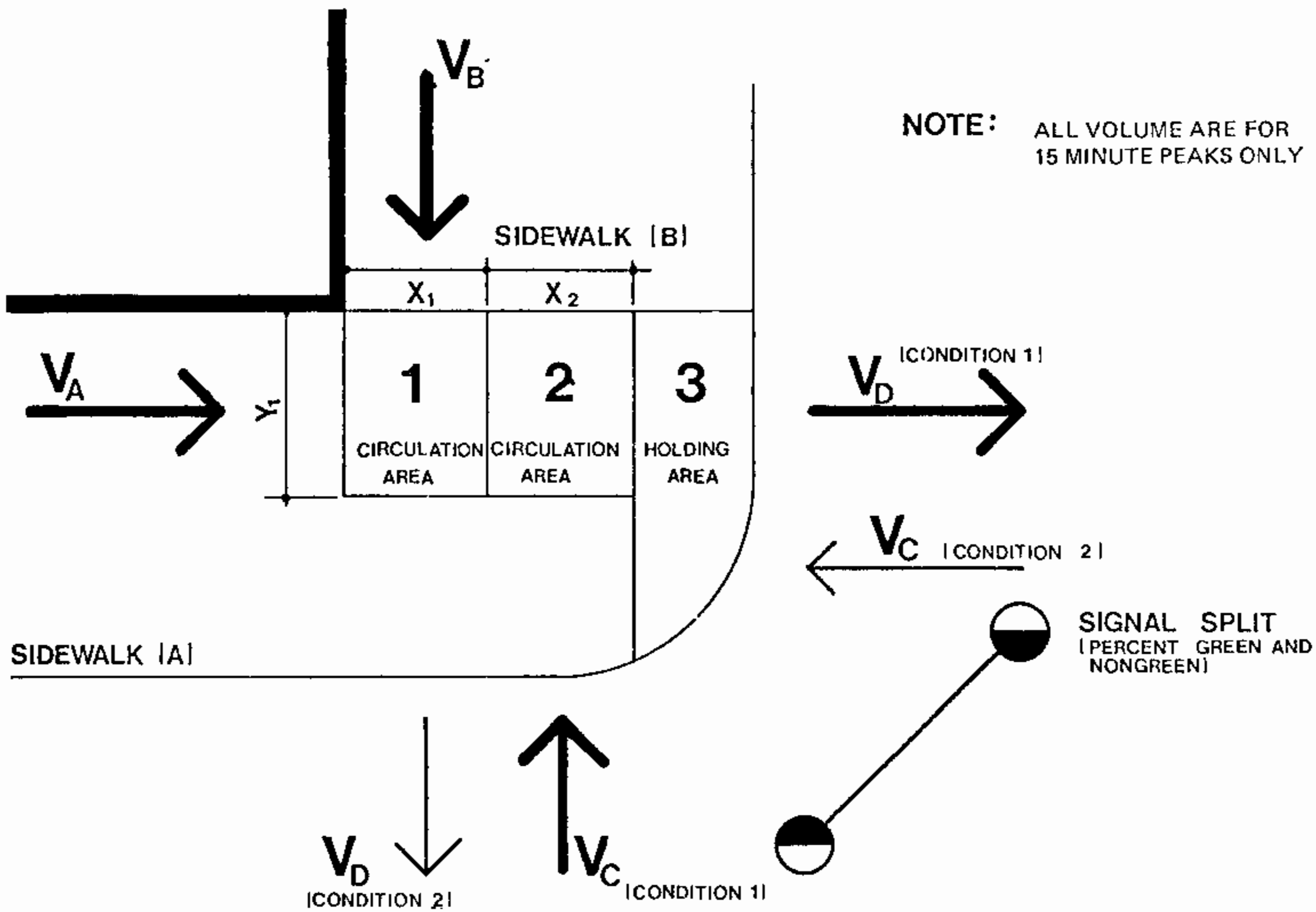


FIGURE 11-4

Area Required For Condition 1

Procedures for Determining Area Required at Intersections With Standard Signal Phasing

The following procedures have been developed for estimating intersection area requirements for standard signal phasing conditions. The basic methodology follows the general procedures of Section 13.7.2.

1. Determine the location of volume vectors V_A, V_B, V_C and V_D (See Figure 11-3, 11-4).

Each intersection has various characteristics which determine the maximum total area required in terms of allowing pedestrians to circulate through the intersection as well as allowing pedestrians to queue in a holding area waiting to cross the street.

There are two basic sets of variables which are considered in determining the maximum area required at a given intersection:

(1) The incoming and outgoing volumes and their interrelationship and,

(2) The total signal cycle time as well as the signal split (percent green and non-green time)

To facilitate the process of estimating the maximum required area, the nomenclature illustrated in Figures 11-3 and 11-4 was established. This nomenclature assumes the location of volume vectors V_A and V_B and thus defines their relationship with respect to the other volume vectors and signal split conditions at each of the intersection crosswalks. These volume vectors (V_A and V_B) must always be positioned as illustrated in Figure 11-3 and 11-4 when using the procedures described in the following section. In addition, pedestrian flows entering the intersection from the crosswalk are defined as V_C vectors (incoming) and those pedestrian flows leaving the intersection and entering the crosswalk are defined as V_D vectors (outgoing).

2. Determine adjusted hourly volume at intersection for pedestrian volumes V_A, V_B, V_C and V_D.

a. For V_A and V_B (volumes)

$$V_A \text{ (hr)} = \frac{V_A \text{ 60 min. (1.33)}}{\text{15 min.}} \quad \text{or}$$

V_A (hr) = V_A (5.32) where

V_A (hr) = Adjusted hourly volume at the intersection

V_A = 15 min. peak flow into intersection

1.33 = Surge rate adjustment for platooning for the 1 min. peak within the 15 min. peak period

b. For V_c (volume)

$$V_c \text{ (hr)} = 4 \ V_c \ \frac{(T.S.)}{(T.G.)}$$

where:

$V_{C(HR)}$ = Adjusted hourly volume at intersection

V_C = 15 min. peak flow into intersection

*T.S. = Total signal cycle time (sec.)

*T.G. = Total green time (sec)/cycle, minus 3 sec. start up time.

*Standard signal phasing:

For the purposes of our calculations we have assumed the following in terms of signal time and percent split:

Signal Cycle Time - The condition most commonly found in urbanized areas is a 80 second cycle length.

In the event that 80 seconds is not the length of the signal cycle, the equations for estimating the area required cannot be used. For this eventuality, the actual signal cycle time as well as the actual signal split must be used in the above equation to calculate the adjusted values and the equations used in estimating the area required must be modified accordingly.

Signal Split - The most common condition encountered in urbanized areas is a 40/60 - 60/40 or 50/50 split depending upon the nature of vehicular traffic flows along intersecting streets.

Therefore using the formula above; equations have been established to determine volumes for three standard signal conditions:

(1) For 40/60 split - 80 sec. total - 32 sec. green - 48 sec. nongreen
(2) For 60/40 split - 80 sec. total - 48 sec. green - 32 sec. nongreen
(3) For 50/50 split - 80 sec. total - 40 sec. green - 40 sec. nongreen

(Note: Green time must be reduced by 3 seconds for start-up delay time when the light changes to green.)

For condition (1) $V_{C_{hr}} = 4\ V_c \frac{(80)}{(29)}$ or $V_{C_{hr}} = 11\ V_C$

For condition (2) $V_{C_{hr}} = 4\ V_c \frac{(80)}{(45)}$ or $V_{C_{hr}} = 7\ V_C$

For condition (3) $V_{C_{hr}} = 4\ V_C \underline{(80)}$ or $V_{C_{hr}} = 8.6\ V_C$

c. For V_D Volume:

$$V_{D_{hr}} = \frac{V_D\ 60\ \text{min.}\ (1.33)}{15\ \text{min.}} \quad \text{Or}$$

$$V_{D_{hr}} = V_D\ 5.32$$

3. Determine Area #1

Area #1 (See Figure 11-3 and 11-4)

where:

Y_1 = effective width required by V_A

X_1 = effective width required by V_B

The equation for calculating effective width is:

$Y = .308\ (X^{.439})$ where

Y = Effective width in feet

X = Hourly volume (adjusted 15 min. volume as previously noted)

The minimum acceptable dimension for V_A and V_B is 5 ft. Fig. 11-5 reflects this threshold at the lower end of the V_0 curve.

Therefore using the equation for effective width Area #1 can be represented as follows:

$$\text{Area \#1} = .308\ \left(V_A\ (5.32)\right)^{.439}\ \ .308\ \left(V_B\ (5.32)\right)$$

or

Equation (I) $$\text{Area \#1} = .41 \left[\left(V_A^{\ .439}\right)\left(V_B^{\ .439}\right)\right]$$

where:

V_A and V_B = 15 min. unadjusted peak volume.

4. Determine Area #2 (See Figure 11-3)

Area #2 = (Y_1) (X_2) for <u>Condition 1</u> or

Area #2 = (Y_2) (X_1) for <u>Condition 2</u>

where

Y_1 = Eff. width required by V_A (both conds.)

X_2 = Eff. width required by V_C (Cond. 1)

Y_2 = Eff. width required by V_C (Cond. 2)

X_1 = Eff. width required by V_B (both conditions)

Since the adjusted hourly volume of V_C is dependent upon the signal cycle length and percent split for the various signal phases, Area #3 can be represented as follows:

a. Condition 1 (See Figure 11-3):

40/60 split - 80 sec. total cycle 32 sec. green - 48 sec. nongreen

$$\text{Area \#2} = \left[.308 \left(5.32\ V_A\right)^{.439}\right] \left[.308 \left(11\ V_C\right)^{.439}\right]$$

or,

Equation II $$\text{Area \#2} = .57 \left[\left(V_A{}^{.439}\right)\left(V_C{}^{.439}\right)\right]$$

b. Condition 1 (See Figure 11-1):

60/40 split - 80 sec. total cycle - 48 sec. green - 32 sec. nongreen

$$\text{Area \#2} = \left[\left(.308 \left(5.32\ V_A\right)^{.439}\right] \left[.308 \left(7\ V_C{}^{.439}\right)\right]$$

or,

Equation III $$\text{Area \#2} = \left[.308\ (5.32\ V_A)^{.439}\right] \left[.308\ (7V_C)^{.439}\right]$$

c. Condition 1 (See Figure 11-2):

50/50 split 80 sec. total - 40 sec. green - 40 sec. nongreen

$$\text{Area \#2} = \left[.308\left(5.32\ V_A\right)^{.439}\right] \left[.308\left(8.6\ V_C\right)^{.439}\right]$$

or

Equation IV   Area #2 $= \left[\left(.51 \quad V_A{}^{.439}\right)\left(V_C{}^{.439}\right)\right]$

d. Condition 2 (Figure 11-4)

As previously noted for Condition 2

Area #2 $= (Y_1)\ (X_1)$

Since (X_1) is a function of V_B, the equations developed above for Condition 1 will be the same for Condition 2 when V_B is substituted for V_A. Therefore for each signal split the following equations are used to determine Area #2;

For 40/60 split:

Equation V   Area #2 $= .57\left[\left(V_B{}^{.439}\right)\left(V_C{}^{.439}\right)\right]$

For 40/60 split:

Equation VI Area #2 $= .46\left[\left(V_B{}^{.439}\right)\left(V_C{}^{.439}\right)\right]$

and for 50/50 split:

Equation VII   Area #2 $= .51\left[\left(V_B{}^{.439}\right)\left(V_C{}^{.439}\right)\right]$

5. Determine Holding Area #3

Based upon the general procedures described previously in the Procedures Section 13.7.2, the holding Area #3 is calculated as follows:

$$\text{Area \#3} = \frac{V_D\ (1.33) \quad \text{T.N.(Sec)} \quad 5(\text{Sq.Ft})}{15\ (\text{min}) \qquad 60\ (\text{sec})}$$

V_D = unadjusted 15 min. peak volume

T.N. = nongreen signal time (sec)

1.33 = surge rate adjustment

5 = minimum density module for queuing per person (in sq. ft.)

(15) = adjustment for one min.

(60) = adjustment for one sec.

Area #3 is dependent upon the signal cycle. Length as well as the signal split in terms of percent nongreen signal time. For the various signal splits, Area #3 can be represented as follows:

a. For 40/60 split - 80 see total cycle - 32 sec. green

Eq. VIII Area #3 = $.36\ V_D$ (in sq. ft.)

b. For 60/40 split - 80 sec. total 48 sec. green - 32 sec. nongreen

Eq. IX Area #3 = $.24\ V_D$

c. For 50/50 split - 80 sec. total - 40 sec. green - 40 sec. nongreen

Eq. X Area #3 = $.30\ V_D$

6. Determine Total Area Required at Intersection

For each condition (specified in Figure 11-3 and 11-4). The total area required is:

Total Area = Area #1 and Area #2 and Area #3

Therefore the total area required for each condition is represented on Table 11-1 below.

7. Testing for the Maximum Area Required at the Intersection

The maximum area required at a given intersection is a function of:

a. Signal cycle duration.
b. Signal split - percent green time, present nongreen time.
c. The location as well as the volumes of the incoming and outgoing vectors V_A, V_B, V_C, and V_D.

The signal cycle duration as well as the split in terms of green and nongreen time are given for any intersection. In addition the position and volume of the V_A and V_B vectors are fixed and do not vary for any given condition.

However, there are two alternatives for positioning vectors V_C and V_D as illustrated in Figures 11-3 and 11-4 as a function of each phase of the signal.

Therefore each phase of the signal cycle must be tested because the maximum area required in terms of Areas #1, #2 and #3 will vary as a function of each phase of the cycle.

As illustrated in Figure 11-3 for the first condition V_C and V_D are assumed in the positions shown and the maximum area requirement is determined.

A SIGNAL SPLIT	CONDITION	AREA NO. 1 (+)	AREA NO. 2 (+)	AREA NO. 3	=	TOTAL AREA REQUIRED
50/50	Condition 1 V_d → ↑ V_c	(EQ I) + $.41\left[(V_a^{.439})\ (V_b^{.439})\right]$	(EQ IV) + $+.51\left[(V_a^{.439})\ (V_c^{.439})\right]$ +	(EQ X) $\left[.30\ V_d\right]$	=	$V_a^{.439}\left[.41V_b^{.439} + .51V_c^{.439}\right] + .3V_d$
50/50	Condition 2 ← V_c ↓ V_d	(EQ I) + $.41\left[(V_a^{.439})\ (V_b^{.439})\right]$	(EQ VII) + $+.51\left[(V_b^{.439})\ (V_c^{.439})\right]$ +	(EQ X) $\left[.30\ V_d\right]$	=	$V_b^{.439}\left[.41V_a^{.439} + .51V_c^{.439}\right] + .3V_d$
40/60 V_c has 40% green V_d has 40% non-green	Condition 1 (60/40) V_d → ↑ V_c (40/60)	(EQ I) + $.41\left[(V_a^{.439})\ (V_b^{.439})\right]$	(EQ II) + $+.57\left[(V_a^{.439})\ (V_c^{.439})\right]$ +	(EQ IX) $\left[.24\ V_d\right]$	=	$V_a^{.439}\left[.41V_b^{.439} + .57V_c^{.439}\right] + .24V_d$
40/60 V_c has 60% green V_d has 60% non-green	Condition 2 60/40 ← V_c V_d ↓ 40/60	(EQ I) + $.41\left[(V_a^{.439})\ (V_b^{.439})\right]$	(EQ VI) + $+.46\left[(V_b^{.439})\ (V_c^{.439})\right]$ +	(EQ VIII) $\left[.36\ V_d\right]$	=	$V_b^{.439}\left[.41V_a^{.439} + .46V_c^{.439}\right] + .36V_d$
60/40 V_c has 60% green V_d has 60% non-green	Condition 1 (40/60) V_d → ↑ V_c (60/40)	(EQ I) + $.41\left[(V_a^{.439})\ (V_b^{.439})\right]$	(EQ III) + $+.46\left[(V_a^{.439})\ (V_c^{.439})\right]$ +	(EQ VIII) $\left[.36\ V_d\right]$	=	$V_a^{.439}\left[.41V_b^{.439} + .46V_c^{.439}\right] + .36V_d$
60/40 V_c has 40% green V_d has 40% non-green	Condition 2 ← V_c (40/60) V_d ↓ (60/40)	(EQ I) + $.41\left[(V_a^{.439})\ (V_b^{.439})\right]$	(EQ V) + $+.57\left[(V_b^{.439})\ (V_c^{.439})\right]$ +	(EQ IX) $\left[.24\ V_d\right]$	=	$V_b^{.439}\left[.41V_a^{.439} + .57V_c^{.439}\right] + .24V_d$

TABLE 11-1

Required Area Equations Summary

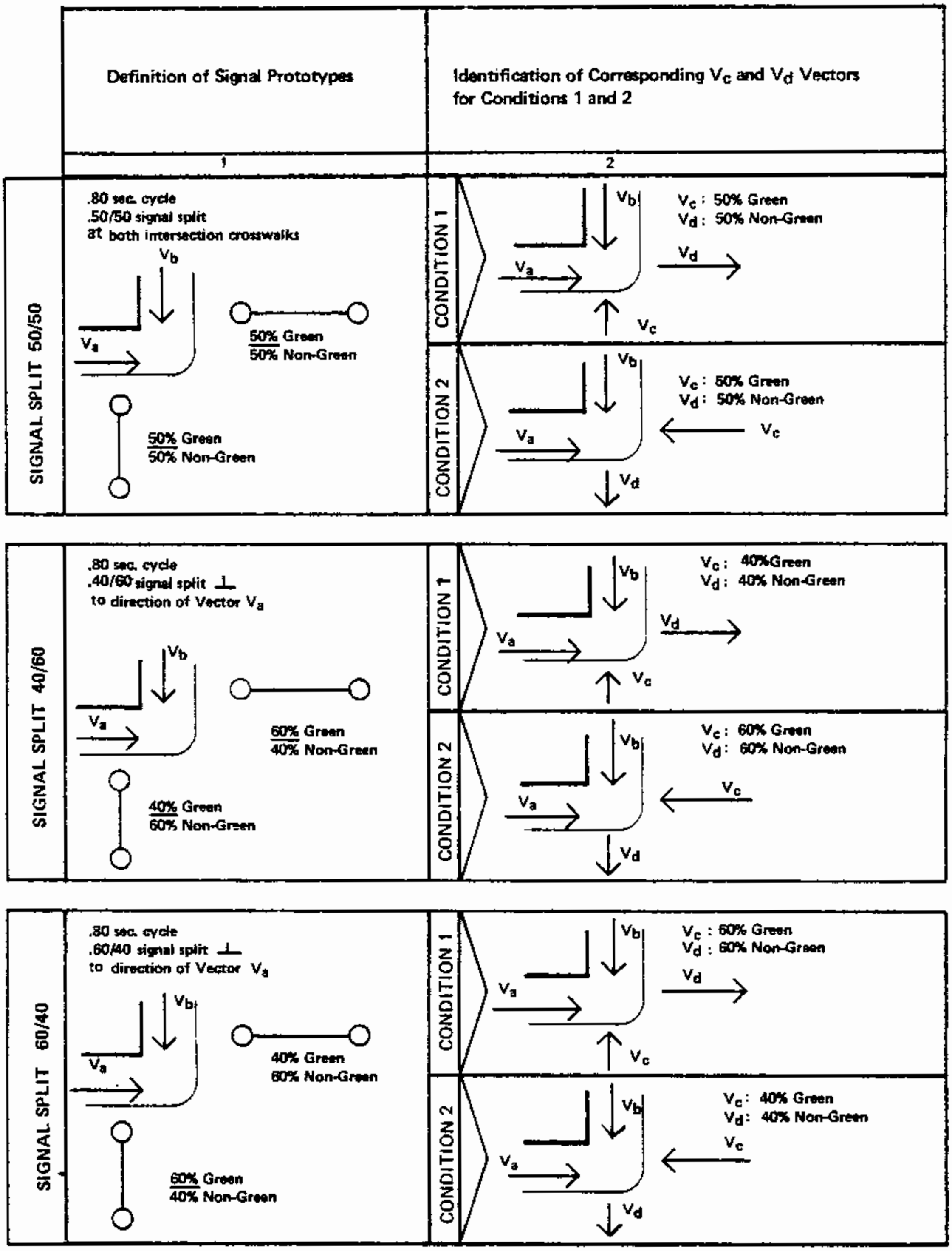


TABLE 11-2

Framework For Evaluating Intersection Area Requirements

Determination of V_o From FIG. 11-5 Where: $V_o = V^{.439}$ (V = 15 Min. Peak)		Required Intersection Area Equations for Conditions 1 and 2
For V =	V_o =	
3	4	5
V_a =	V_{ao} =	$A_1 = V_{ao} \left[.41\ V_{bo} + .51\ V_{co}\right] + .3\ V_d$
V_b =	V_{bo} =	
V_c =	V_{co} =	
V_d =	(NA)	
V_a =	V_{ao} =	$A_2 = V_{bo} \left[.41\ V_{ao} + .51\ V_{co}\right] + .3\ V_d$
V_b =	V_{bo} =	
V_c =	V_{co} =	
V_d =	(NA)	

V_a =	V_{ao} =	$A_1 = V_{ao} \left[.41\ V_{bo} + .57\ V_{co}\right] + .24\ V_d$
V_b =	V_{bo} =	
V_c =	V_{co} =	
V_d =	(NA)	
V_a =	V_{ao} =	$A_2 = V_{bo} \left[.41\ X_{bo} + .46\ V_{co}\right] + .36\ V_d$
V_b =	V_{bo} =	
V_c =	V_{co} =	
V_d =	(NA)	

V_a =	V_{ao} =	$A_1 = V_{ao} \left[41\ X_{bo} + .46\ V_{co}\right] + .36\ V_d$
V_b =	V_{bo} =	
V_c =	V_{co} =	
V_d =	(NA)	
V_a =	V_{ao} =	$A_2 = V_{bo} \left[.41\ V_{ao} + .57\ V_{co}\right] + .24\ V_d$
V_b =	V_{bo} =	
V_c =	V_{co} =	
V_d =	(NA)	

TABLE 11-2 (CONT'D)

Framework For Evaluating Intersection Area Requirements

Area Required (Greater of Two Required Areas for Conditions 1 and 2)	Area Available Determined from Fig. 11-7	Adequacy of Area Available Sufficient if: $100 \left[\frac{A_{req} - A_{avail}}{A_{avail}} \right] \leq 10\ \%$
A_{req}	A_{avail}	
6	7	8

TABLE 11-2 (CONT'D)

Framework For Evaluating Intersection Area Requirements

As illustrated in Figure 11-4 for the second condition V_C and V_D are assumed in the positions shown and the maximum area requirement is determined. (The values of V_C and V_D are not the same for the first and second condition.)

The greater area for either condition is used for assessing the adequacy of the area available. If the maximum area required is within 10% of the available area, this will be adequate for accommodating both the area for circulation as well as the holding area.

The procedures for testing each condition at an intersection are as follows:

a. Identification of signal split prototpe

For an 80 second signal cycle and signal splits of 50/50, 60/40 and 40/60, three (3) signal prototypes exist and are identified in Column 1 of Table 11-2. The prototypes are defined by the signal split at each crosswalk and their location with respect to vector V_A:

Prototype 50/50 -

The signal split is 50/50 for both crosswalks.

Prototype 60/40 -

The 60/40 signal split is located perpendicular to the folow of volume vector V_A.

Prototype 40/60

The 40/60 signal split is located perpendicular to the flow of volume vector V_A.

To proceed in testing for the maximum area requirements, the user must first determine which of the 3 prototypes correspond to the conditions of the intersection being analyzed. This is done by finding the match between the signal split/V_A relationship of the specific intersection and one of the three prototypes illustrated on Table 11-2. There will be one and only one match.

b. Determine appropriate V_C and V_D vectors for Conditions 1 and 2.

Once the appropriate signal prototype has been identified, each phase of the signal cycle must be tested, as each generates a different area requirement.

In column 2 of Table 11-2, the appropriate V_C and V_D volume vectors used in testing each of the two phase conditions are identified. These vectors represent the pedestrian volumes for each signal phase that are being held at the intersection of one crosswalk and those volumes entering from the other crosswalk. The specific intersection volumes for each vector are entered in column 3 of Table 11-2.

c. Calculating Area Requirements for Conditions 1 and 2.

For each condition, the total area requirement at the intersection can be determined using the equations appearing in the right hand column of Table 11-1. For the purpose of simplifying the calculations, the graph in Figure 11-5 was developed to provide the value V_0 for volume vectors to the .439 power thus for V_A .439, V_B .439 and V_C .439:

$$V_{A0} = V_A^{.439}$$

$$V_{B0} = V_B^{.439}$$

$$V_{C0} = V_C^{.439}$$

To find the value of a given volume, $V_A^{.439}$, $V_B^{.439}$ or $V_C^{.439}$, the V scale at the bottom of Figure 11-5 with any V_A, V_B or V_C volume up to 2400 ped/15 min. and follow the volume line up to the intersection of the curve. Then simply read the corresponding V_0 value on the left hand scale. When using this procedure enter the V_{A0}, V_{B0} and V_{C0} values in column 4 of Table 11-2:

By substituting the subscripts V_{A0} for $VA^{.439}$, V_{B0} for $V_B^{.439}$ and, V_{C0} for $V_C^{.439}$ into the area equations of Table 11-1, the formulas are transposed into those given in column 5 of the Table 11-2.

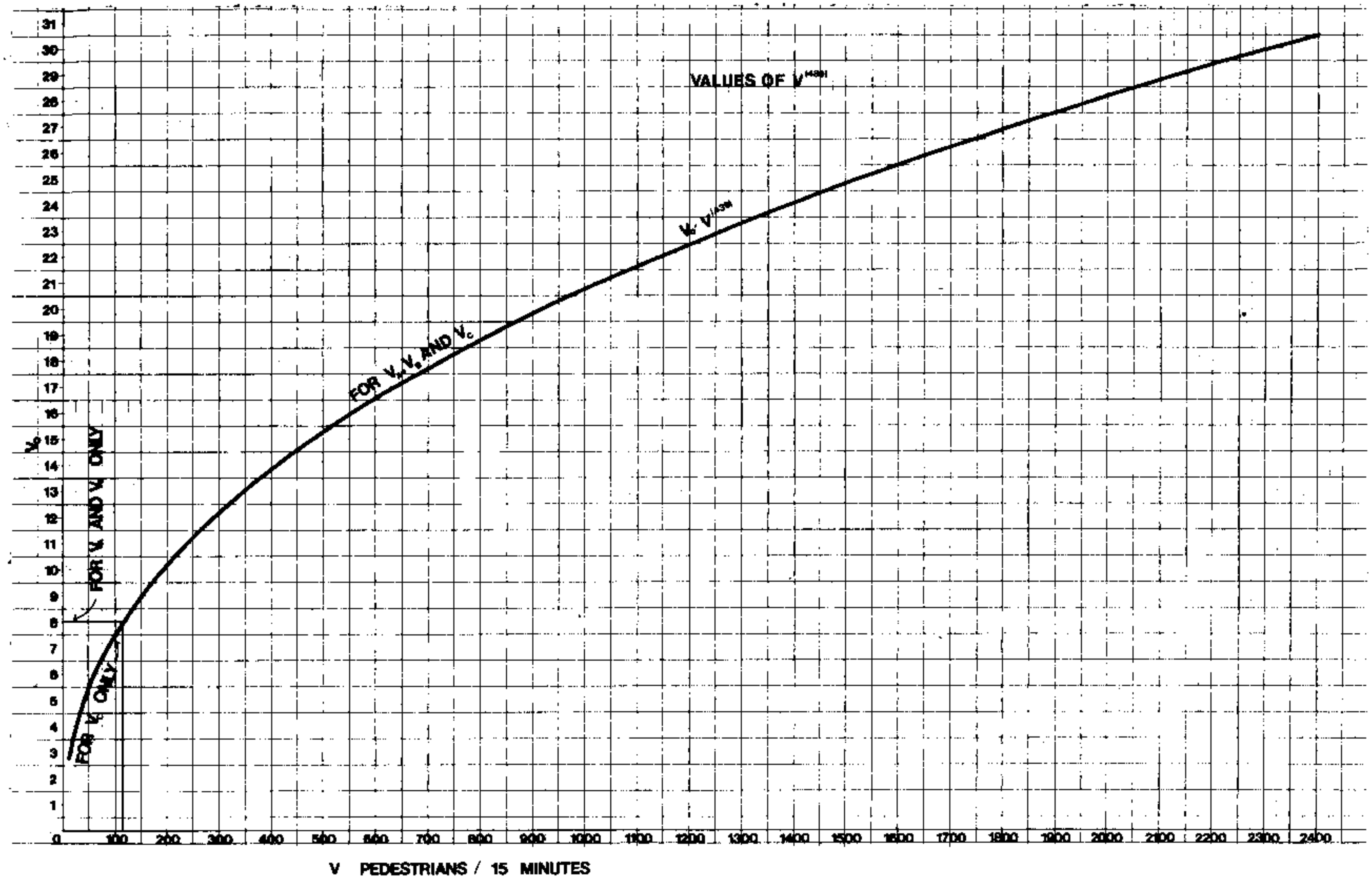


FIGURE 11-5

Valves Of V $^{(.439)}$

By entering the V_{AO}, V_{BO}, V_{CO}, V_D values into the corresponding equations in Table 11-2 the area requirement for conditions 1 and 2 can be solved. The greater of the two area requirements should be entered in Column 6.

8. Available Area (See Figure 11-6)

From previous procedures, the available area (AA) at the intersection of two sidewalks is equal to:

$(AA) = 1.67\ (x)\ (y)\ -\ .215R^2$ where,

AA = Area Available

(X) = Total width of sidewalk (X) including effective width plus ancillary area.

(Y) = Total width of sidwalk (Y) including effective width plus ancillary area.

(R) = Curb radii at intersection

Figure 11-7 illustrates the maximum area available for various combinations of intersecting sidewalk widths. The value of (R) was assumed as follows:

R = 8 ft. for 8 ft. sidewalk widths
R = 10 ft. for 10 ft. sidewalk widths
R = 12 ft. for 12 ft. sidewalk widths
R = 15 ft. for 15 ft. and greater sidewalk widths

For two intersecting sidewalks of different widths, R is equal to the dimension of the lesser width.

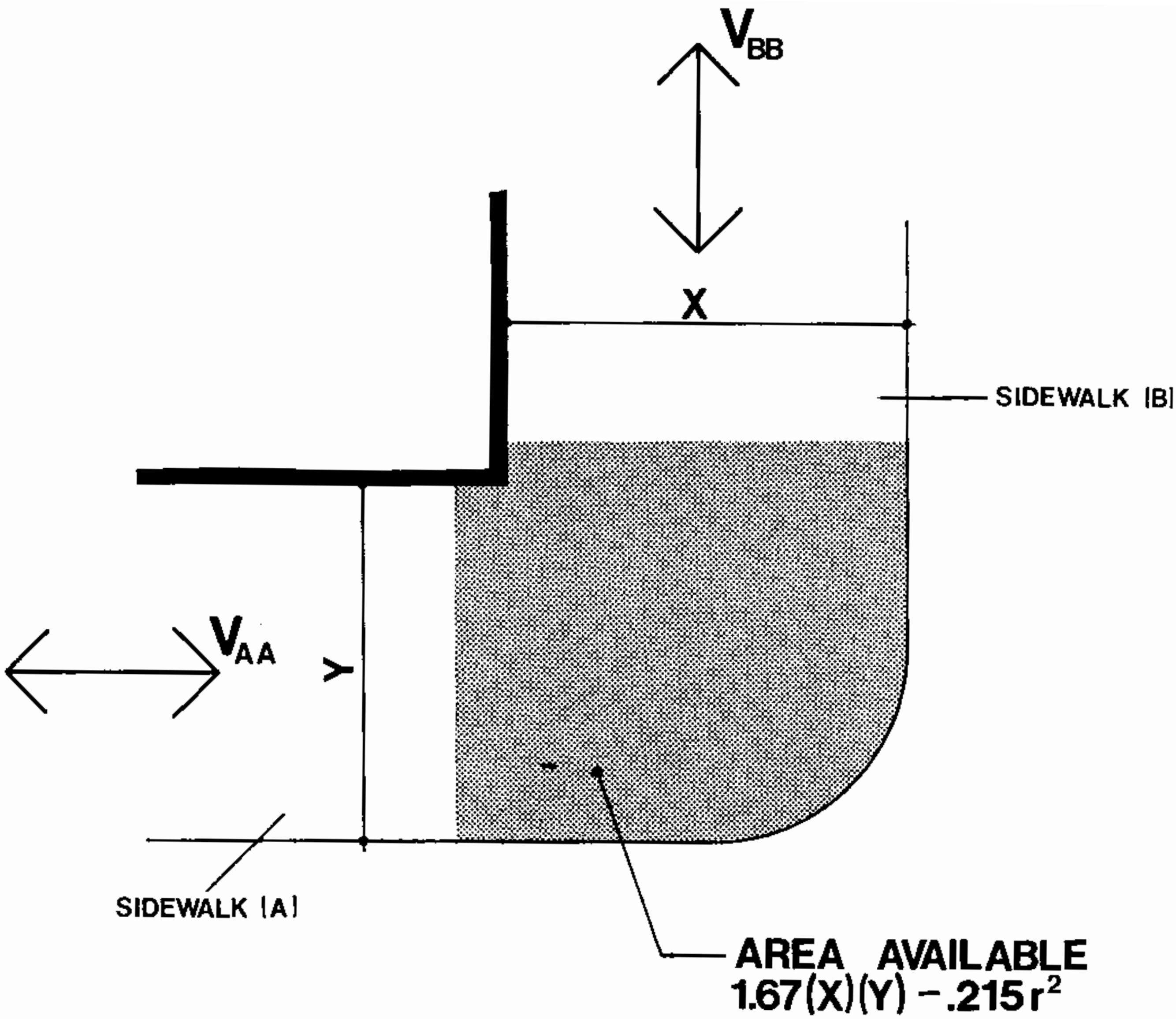
The total width of sidewalk (X) and (Y) includes the effective width plus ancillary area.

The effective width of sidewalk (X) or (Y) at midblock is based upon peak hourly, two-directional volumes on each sidewalk. (Vectors A and B in Figure 11-6).

The equation for calculating effective width is as follows:

$Y = .308 \cdot 4\ V_A^{\ .439}$

where,



NOTE: ALL VOLUMES ARE FOR 15 MINUTE PEAKS ONLY

FIGURE 11-6

Area Available

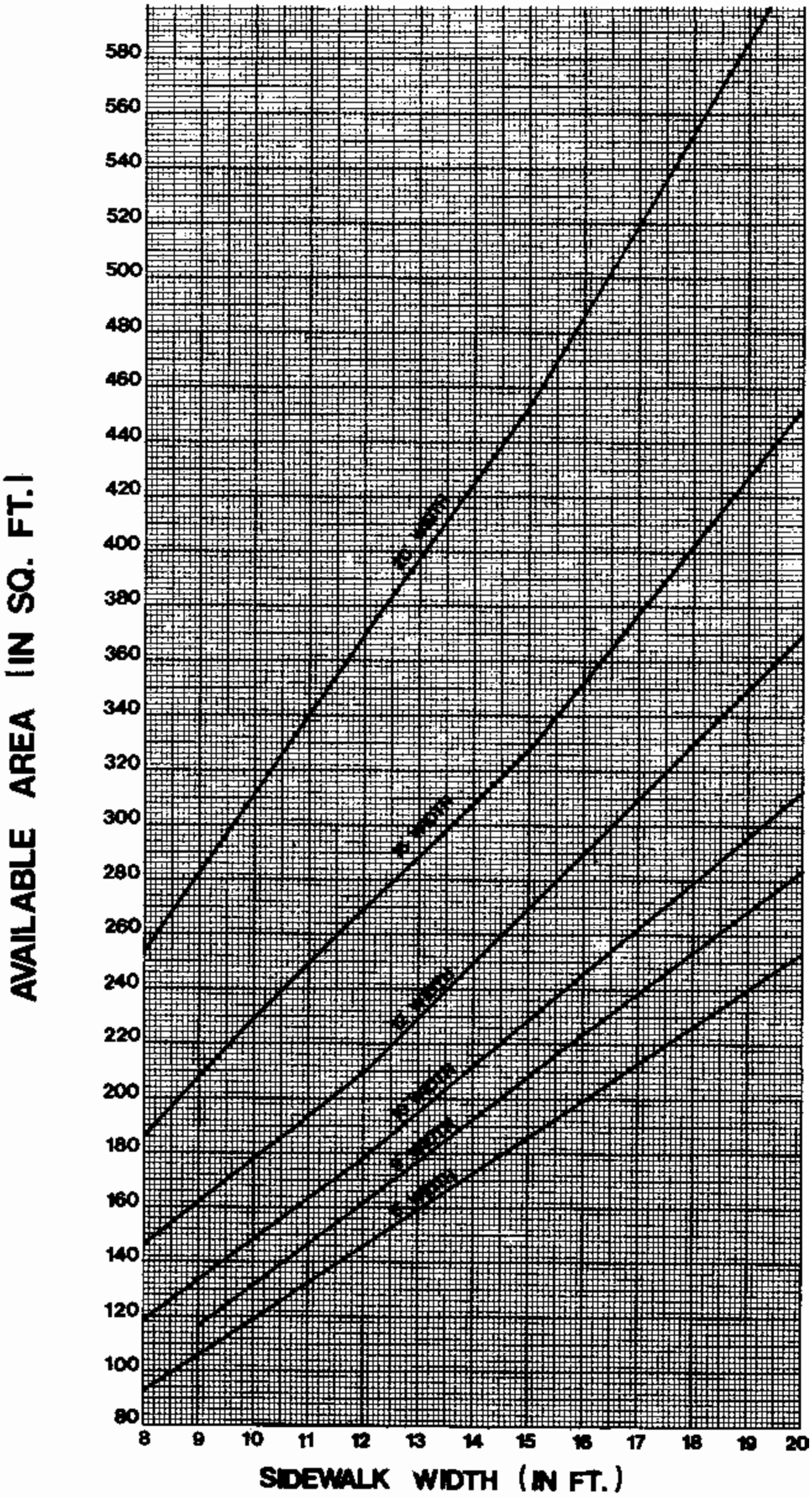


FIGURE 11-7

Available Intersection Area

Y = effective width (in ft.)

V_A = 15 min. peak volume in both directions and

(4) = constant to adjust 15 min. volume to 60 min. (one hour) volume.

a. Assignment of Volumes (See Figure 11-5 for V_A and V_B)

The assignment model (described in the procedures) will identify pedestrian flow volumes for the 15 min. peak period. This volume has been adjusted within the model to account for the 15 min. peak period within the peak hour. To calculate the hourly volume, the 15 min. volume is multiplied by 4. (60 min.)

The total sidewalk width at midblock also includes the ancillary area required. This area is a function of the conditions abutting the pathway and its determination has been decribed previously in the Procedures, Section 13.7.1.

9. Assess the adequacy of the available area at the intersection.

The available area that was determined for the intersection by using Figure 11-7 should be entered in Column 7 of Table 11-2. The available area should be considered sufficient if the required area in column 6 is not more than 10% greater. To determine the percentage subtract the required area from the available area, then divide the result by the available area and multiply by 100, i.e.,

$$100 \quad \frac{(\text{Required Area}) - (\text{Available Area})}{(\text{Available Area})}$$

= percentage difference

Enter this value into column 8 of Table 11-2.

SUPPLEMENT 12

DISCUSSION OF METHODS AND FACILITIES FOR PEDESTRIAN/VEHICLE SEPARATION

The primary example of an entire system of vehicle-dominant pathways is the parallel grid system of ordinary sidewalks that has grown out of years of common use of streets and roadways by both vehicles and pedestrians. Pedestrian-dominant pathway elements usually incorporate some means of separating pedestrians and vehicles to an extent greater than that provided by the familiar sidewalk grid. In the following section, an inventory of various facilities designed specifically to accommodate pedestrian movement is provided and discussed.

12.1 Pedestrian Facilities

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

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

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

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

In the following sections, representative types of separation are discussed. This discussion centers around the separation typology illustrated in Table 12-1 and is intended to be an overview of the numerous ways in which pedestrian and vehicular movement can be separated. Of course, variations on these basic themes are possible. Emphasis in the following discussion is on static facilities, and while analogous mechanical systems exist for many of these elements, they are not covered here.

TABLE 12-1

Typology of Separated Pedestrian Systems and Facilities

HORIZONTAL SEPARATION

PARALLEL ELEMENTS

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

DISPLACED ELEMENTS

- Displaced Sidewalk Grids
- R.O.W. within Land Use Development Parcel or Building Structure
- Alleyways
- Full Malls
- Street Closings (including play streets)

VERTICAL SEPARATION

BELOW-GRADE ELEMENTS

- Tunnels, Subwalks, Subways

ABOVE-GRADE ELEMENTS

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

TIME DISPLACEMENT

- Crosswalks (intersection and midblock)
- Street Closings (temporary)

VERTICAL CONNECTIONS

- Stairs
- Ramps
- Escalators
- Elevators

12.2 Horizontal Separation

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

- Parallel - Systems that accommodate pedestrian movement at grade parallel and immediately adjacent to vehicular movement; and

- Displaced - Systems which, as a function of their location, are characterized by physical displacement from the vehicle network.

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

Sidewalks

Sidewalks may be widened, as shown in Figure 12-1, by transforming existing parking lanes into added sidewalk space. The added space can then be used to partially buffer pedestrian movement from vehicular movement by the use of plantings, benches and similar barriers.

Partial Malls

The partial mall is simply a more complete treatment of the widened sidewalk. Vehicular intrusion may be limited to buses and taxicabs only, although through traffic can be allowed on all cross streets perpendicular to the mall. Partial malls have most of the advantages and disadvantages of sidewalk widenings, except where transit service to shoppers and workers in the area is improved by excluding other vehicles, and using part of added pedestrian space for bus shelters.

Arcade Setbacks

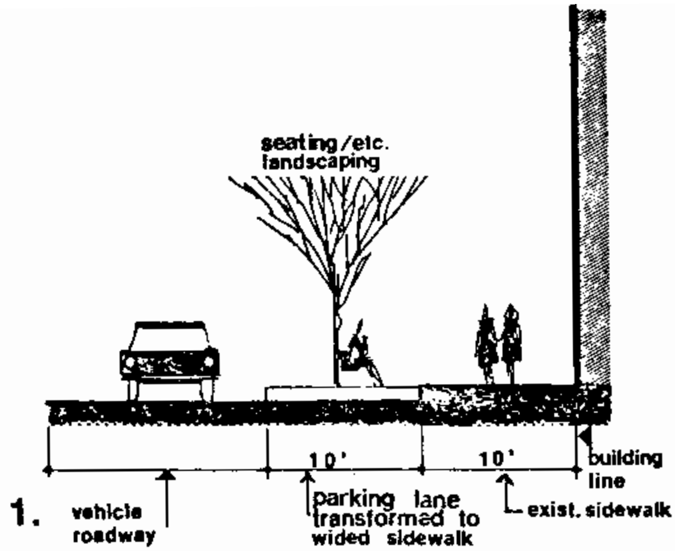
In new construction, or where old construction is being remodeled or rebuilt, the building abutting the sidewalk can be recessed to create additional pedestrian space as shown in Figure 12-2. This provides the advantages of sidewalk widening while maintaining the original roadway width. It also provides partial cover from the elements.

Full Malls

Full malls, shown in Figure 12-3 are probably the best-known examples of horizontal, pedestrian-vehicular separation. They usually occur when a main shopping street is closed to all but emergency traffic; traffic may be maintained on all, some or none of the cross streets within the mall area. Temporary street closing (separation by time) is a special case of this treatment. Malls can be covered or enclosed to provide benefits to pedestrians beyond those provided by separation.

Displaced Grids

A displaced grid of horizontally separated pedestrian walkways is often configured as shown in Figure 12-4. To some cases this treatment can be created by converting alleys into pedestrian space, and opening the backs of retail shops abutting the alleys; the store backs then become the store fronts. In other cases, the displaced grid may be formed by shopping arcades or lobbies within the interior of office building or hotels.



ADVANTAGES

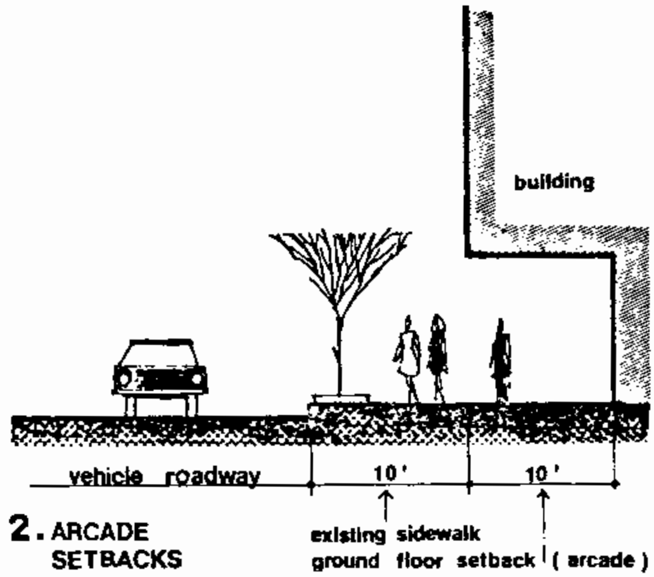
- Increased sidewalk space relieves pedestrian congestion in areas of high volume
- Additional buffer zone reduces potential for conflict and accident
- Annoyance of noise and fumes reduced
- Visual obstruction of parked autos eliminated
- Increases space for pedestrian amenities

DISADVANTAGES

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

FIGURE 12-1

Sidewalk Widenings



ADVANTAGES

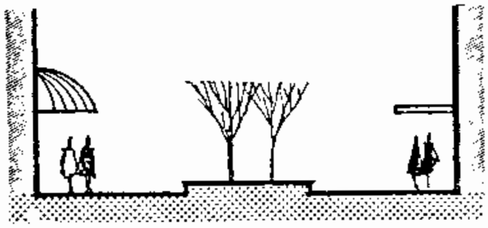
- Relief of pedestrian congestion
- Buffer zone reduces potential for conflict and accident
- Reduced annoyance from fumes and noise
- Increased space for pedestrian amenities
- Some shelter from sun and inclement weather
- Does not reduce vehicle space

DISADVANTAGES

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

FIGURE 12-2

Arcade Setbacks



ADVANTAGES

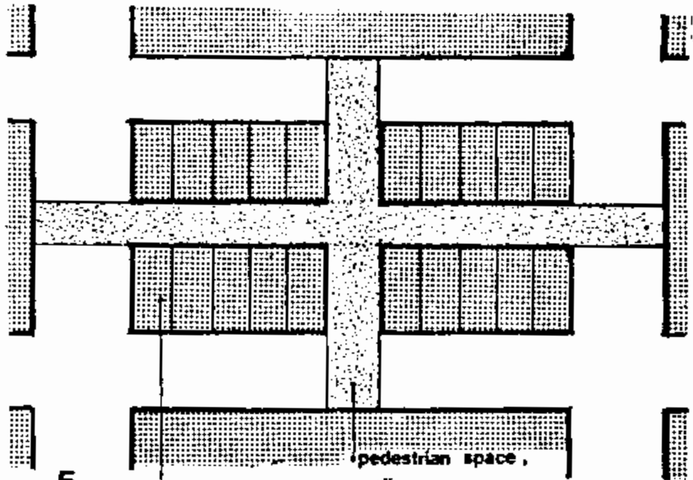
- Eliminates conflict within mall area
- May be integrated with public transit
- Allows use of people-movers, jitneys, etc.
- Can be developed in stages
- Allows a wide range of communal activities (art fairs, craft shows, entertainment, etc.)
- Can integrate with existing parks, plazas, etc. to create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

DISADVANTAGES

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

FIGURE 12-3

Full Malls (Urban Streets)



ADVANTAGES

- Eliminates potential for conflict associated with parallel grid
- Facilities servicing of retail activities with backs to street
- Gives pedestrian direct access to both sides of walkway
- Provides freedom from noise, fumes and visual obstruction of vehicles
- Relieves vehicle congestion at intersection for turning movements
- Midblock pedestrian crossings eliminates conflicts with turning vehicles and simplifies driver attention requirement
- Arcade treatment 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 midblock crossings are not signalized
- Requires extensive remodeling when incorporated into existing buildings.

FIGURE 12-4

Horizontally Displaced Grids

12.3 Vertical Separation

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

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

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

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

Below-Grade Elements

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

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

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

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

The general advantages and disadvantages of below-grade pedestrian systems and system elements are given below in Figure 12-5:

ADVANTAGES

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

DISADVANTAGES

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

FIGURE 12-5

Below-Grade Systems

Above-Grade Elements

Above-grade elements are those in which pedestrian movement occurs above the level of vehicular circulation. General advantages and disadvantages of the systems are given in Figure 12-6. For the purpose of definition, five different types of elevated skyway, or walkway elements are described:

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

Each type is described in Figs. 12-7 thru 12-10. In addition, classification sublevels can be defined based on material, construction type and extent of covering. Due to the large number of possible combinations, however, these lower level elements will be defined as required in the Cost Section (Step 26.2) of the Procedures. The employment of various methods of separation provide a means of minimizing pedestrian/vehicular conflicts in situations where there are high volumes of pedestrian and/or vehicular traffic.

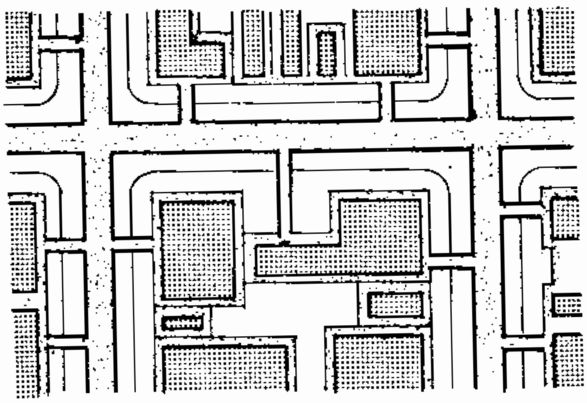
In addition the various methods of pedestrian/vehicular separation will directly affect the disposition of available R.O.W. for the accommodation of pedestrian movement. In this sense, grade separation can be employed to reduce the impact of the pedestrian network upon the available street R.O.W. Various forms of grade separation directly affect the level of both pedestrian and vehicular capacity as they create additional R.O.W.s.

As most alternative forms of horizontal separation have already been considered as part of redistributing vehicular movement (Steps 17.1 thru 17.3) in order to accommodate horizontal pedestrian R.O.W. requirements, attention in this step will primarily be focused upon methods of vertical and time separation.

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

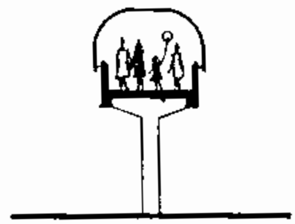
FIGURE 12-6

Advantages and Disadvantages
of Above-Grade Systems



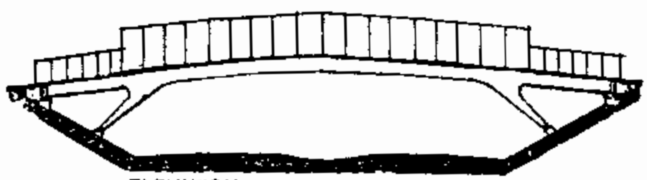
SKYWAY SYSTEM OVER STREET RIGHTS OF WAY

PLAN



Independent

SECTION



ELEVATION

PEDESTRIAN BRIDGE OVER MAJOR ARTERIAL

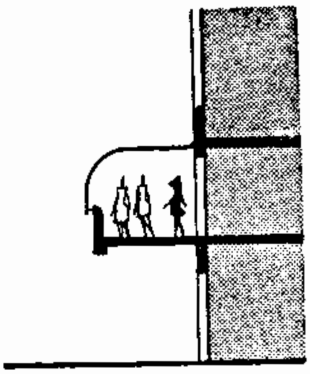
ELEVATION

<u>ELEVATED WALKWAYS (INDEPENDENT)</u>

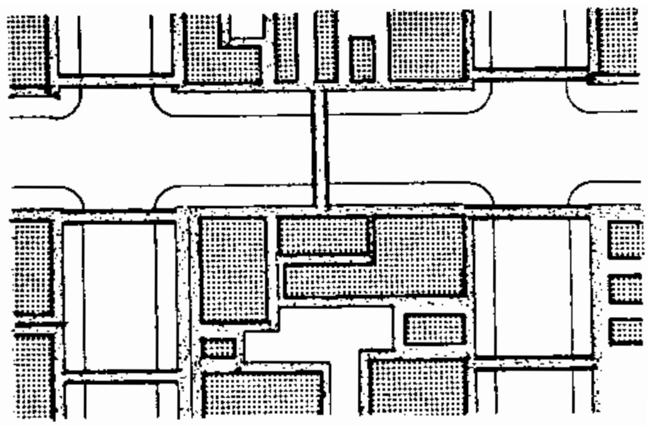
Elements are self-supporting structurally and free-standing. Occur primarily at street crossings parallel to public rights-of-way, and at pedestrian bridges over major arterials.

FIGURE 12-7

Definition And Example Of Independent Elevated And Walkway Elements



Integral flanking



SKYWALK SYSTEM INCORPORATED WITHIN BUILDING PERIPHERIES

SECTION

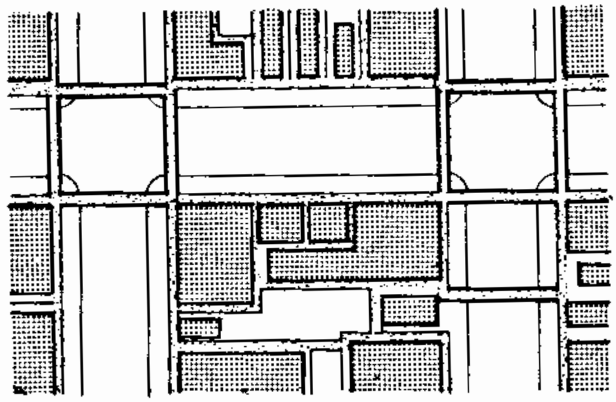
PLAN

ELEVATED WALKWAYS (INTEGRAL)

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

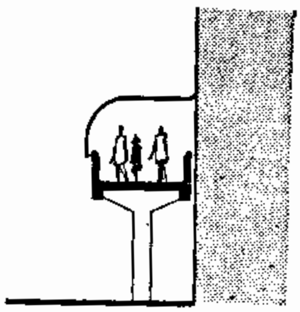
FIGURE 12-8

Description Of Integral Elevated Walkway Elements



ELEVATED SKYWAYS (INDEPENDENT FLANK-ING)

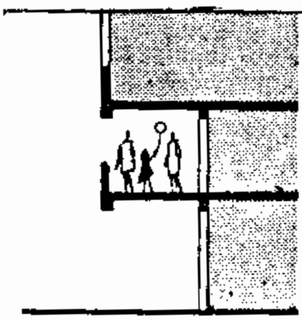
PLAN



Independent-flanking

ELEVATED SKYWAYS (INDEPENDENT FLANKING)

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



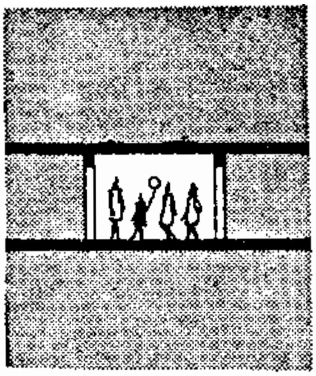
Integral

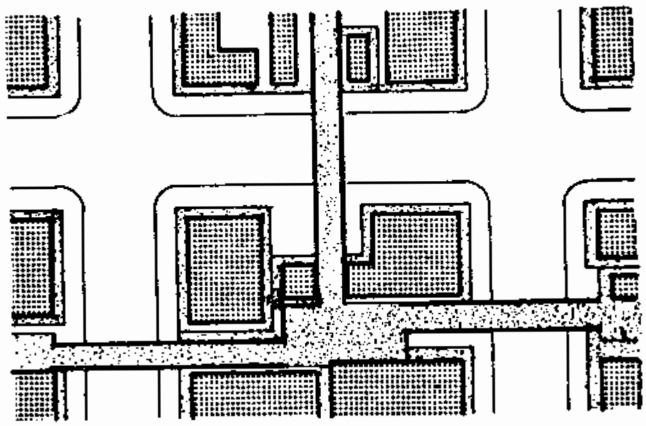
ELEVATED SKYWAYS (INTEGRAL FLANKING)

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

FIGURE 12-9

Description Of Elevated Skyways Flanking Conditions





SKYWALK SYSTEM WITH MIDBLOCK CONNECTIONS

SECTION

PLAN

ELEVATED WALKWAYS (INTERIOR)

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

FIGURE 12-10

Description Of Interior Elevated Walkway Elements

SUPPLEMENT 13

DEFINITION AND DISCUSSION OF CONDITIONS OF APPLICABILITY FOR PEDESTRIAN/VEHICLE SEPARATION

(To be read together with Table 42 in the Procedures.)

13.1 Network Characteristics

1. Pedestrian Network Requirements

In assembling those network characteristics that are relevant in the selection of methods of ped/veh separation, the list of pedestrian network requirements used in Table 32 was reviewed. Those requirements whose satisfaction differed with method of separation were entered separately as column headings under Network Characteristics in Table 42. These are: activity node; function of network; existing dysfunctions; degree of ped/veh conflict; safety; security; pathway directness; and modal interface. In certain specific conditions however, it is conceivable that other pedestrian network requirements could have a relationship which varies with different methods of separation (e.g., countermeasures along a particular segment may be achievable only along an on-grade facility because of site specific conditions). Where such a requirement exists it is to be entered under the column of Pedestrian Network Requirements in the matrix and the methods of separation evaluated and scored against it.

2. Activity Node

An activity node can be the pathway itself and/or the land uses adjacent to it. Whichever the case, activity nodes generally require the following conditions:

- high visibility
- high accessibility
- minimum ped/veh conflict
- adequate capacity

These conditions can be related to the generic aspects of ped/veh separation methods. For example, on-grade methods will generally be more satisfactory than vertically separated methods which may be less accessible and more spatially constrained.

3. Function of Network Segments

This refers to the primary function of functions served by any network segment or subnetwork. Examples might be

- linkage between major activity zones
- access to a major modal interface terminal
- provision of open space

In general, those methods of p/v separation which are

- easily manipulated in terms of configuration (i.e., are flexible and unconstrained)
- generous in terms of their R.O.W.
- high in potential for continuity

will be able to respond well to the primary network function (or functions).

4. Existing Dysfunctions

Needs

This refers to those needs that are to be elicited from users of the pedestrian network. Since the needs are unknown till articulated in the course of applying the PPP, they cannot be evaluated against methods of separation, though they might be relevant consideration in selecting between various methods (e.g., a need for open space would support the selection of an at-grade facility). Thus, the matrix has been scored with non-applicable entries with the exception of partial and full malls. It is assumed that these methods of separation because of their grade connection into the urban fabric and their generous spatial provisions are generally the most capable methods of separation for meeting such needs. Once the needs are known, however, and any relevant ones entered in the blank columns provided in the matrix, the methods of separation must be evaluated against them and scores entered in the matrix. Depending upon the nature of the needs, the weightings pre-assigned for malls and partial malls may be seen as contradictions and thus not be counted in the evaluation procedure or they may be reinforced and remain valid for the accounting procedure.

5. Negative Impacts

This factor calls attention to problems associated with the existing pedestrian network. These may be social, environmental, or economic. The exact relationship between negative impacts and methods of P/V separation can only be calculated when the particular impact is defined.

Space is thus provided in the matrix (see columns 4+ and 5+) so that a variety of impacts can be entered for any segment. In a generic sense, however, one can state that negative impacts are most amenable to resolution where the method of P/V separation provides

(a) adequate capacity
(b) high degree of separation between ped/veh
(c) high continuity
(d) high levels of integration with abutting land uses

6. Degree of Ped/Veh Conflict

Ped/vehicular conflict can manifest itself in various ways: most directly as injury to the pedestrian; more indirectly as congestion and thus time delay to both pedestrian and vehicle; most indirectly in the trips not being made along a particular R.O.W. because of the inconvenience or danger of ped/veh conflict. Generally this conflict is more apparent at intersections.

The conflict will vary with volumes of vehicles, volumes of pedestrians, pathway configuration, and R.O.W. capacities for vehicles and pedestrians, and so on. The greater the degree of conflict, the more applicable will be those p/v separation methods which insure maximum segregation.

7. Safety

Safety refers to

(a) the degree of physical protection afforded the pedestrian from vehicles
(b) the safety associated with the use of the method of separation itself. For example, people are more prone to injure themselves on stairs than ramps.

Some methods of separation, while they may not reduce the impedances (time delays, etc.) associated with ped/vehicle conflicts, might nevertheless make the ped movement safer (e.g., midblock crossings).

8. Security

Security refers to the trip maker's exposure to potential crime, muggings, unease due to "undesirable elements", etc. The trip maker's attitude towards security, whether based on fact or imaginary will strongly affect pathway choice. Those methods of p/v separation that reduce pathway surveillance because they are removed from the general public domain - i.e., from the sight lines or view of passing vehicles or pedestrians or encased within structures or isolated from abutting land uses or allowing of no escape, will be inappropriate where the need for security is high.

9. Pathway Directness

Directness is a measure of pathway impedance related to the time, distance or effort that is required to use a pathway connecting two given centroids.

Those methods of p/v separation that

(a) are relatively independent of the exterior envelope of abutting buildings
(b) are relatively independent of limitations of the sidewalk/street grid pattern

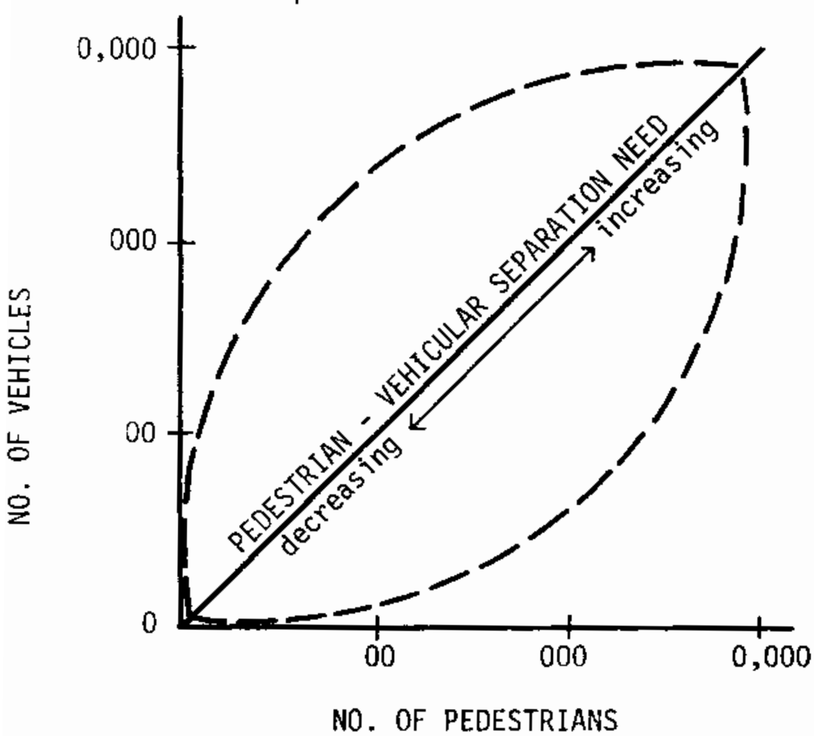
will tend to provide the greatest pathway directness.

10-11. High Pedestrian and Vehicle Volumes

There is a direct, positive and obvious relationship between high volumes of pedestrians on a network and those methods of p/v separation which provide increasingly generous rights-of-way.

It is likewise evident that where high vehicle volumes exist those methods of p/v separation that displace the least amount of vehicular R.O.W. will be the most appropriate.

Where both high ped and high vehicle volumes exist on the same segment, the need for strong measures of ped/veh separation (especially in the form of vertically separated methods) increases accordingly. Graphically this condition can be represented as follows:



12. Imagibility

Imagibility refers to the inherent ability of a given method of separation to create a strong visual statement. The more of the following qualities a method possesses the higher will be its imagibility value:

(a) conceptual clarity or distinctiveness
(b) substantial scale or size
(c) physical differential or separation of the method from the overall environment
(d) general visibility of the method

Though somewhat intangible a characteristic, the importance of imagibility must not be underrated since the creation of a new image for a downtown through the upgrading of the pedestrian environment has frequently been the driving force behind pedestrian planning and design.

13. System Phasing and Implementation

System phasing refers to degree to which various methods of p/v separation lend themselves to incremental installation over time. Horizontal methods of separation that are continuous with the existing circulation system and require some modifications to it are the most amenable to phasing, particularly if they are on rights-of-way under public ownership. Grade separated systems tend to have more critical phasing requirements in that they often must connect specific origins with specific destinations and usually require vertical connections to be in place at given locations. Particularly where such systems are not independent, but integrated with private development, achievement of the desired phasing pattern becomes more difficult.

System implementation refers to problems associated with the actual installation of a pedestrian system. The more a method of separation

(a) is physically independent of other structures
(b) does not displace existing circulation patterns or activities
(c) remains within the same domain of ownership and control,

the easier will be its implementation.

The scoring of Matrix Table 42 reflects the combined considerations of systems phasing and implementation.

14-16. Modal Interface

Modal interface refers, for our purposes, to the relationship between different modes of movement (auto, bus, rapid transit, etc.) and the pedestrian mode. Whether the mode exchanging with pedestrian movement is located or is planned to be located at grade, above grade or below grade has a direct and obvious relationship with methods of separation that are at grade, above grade or below grade. Those systems that can provide grade compatibility for modal interface, will be the most appropriate as the matrix scoring indicates. Since modal interchange facilities (parking lots, transit terminals, etc.) generate a considerable amount of pedestrian traffic, the grade location of modal interchange facilities, either existing or planned, will be a major consideration in the selection of methods of p/v separation. The numerical weightings of this characteristic in the matrix have accordingly been doubled to reflect its importance.

17. Systems Costs

In the procedures for evaluating methods of separation against conditions of applicability, cost considerations have been broken out so that the impact of costs as a final differentiator aiding in the choice among separation methods can be clearly seen. Since the cost consideration is generally of major importance, its weight has been doubled on the matrix.

Systems costs can be separated into capital costs and operating and maintenance costs. A detailed discussion and breakdown of facilities costs is provided in Section 26.5 in the Procedures. The values assigned different separation methods in the matrix is a gross interpretation of this data. In summary one can say that on-grade systems built within existing rights-of-way are least costly, although full malls are an exception. A full mall generally employs paving, landscape, lighting and other features that are initially expensive. In addition, in order to maintain a high standard of upkeep, the maintenance and operating costs exceed that of other on-grade, horizontally separated systems.

Vertically separated systems, particularly below grade, are more expensive; however, those that are internal to a building, or along its perimeter tend to be considerably less costly than physically independent systems.

Clearly only after the architectural/engineering design has been prepared can the actual cost of a segment be determined.

Site Opportunities or Constraints

Certain conditions of applicability are a function of more general contextual issues or constraints rather than being a function of the characteristics of the pedestrian network above. Such issues that exist in a generic sense are entered in the matrix and evaluated against the methods of separation. They are defined and their relationship to method of separation is discussed briefly in the following section.

Certain of the relevant site opportunities or constraints can exhibit variability which would modify or elaborate the appropriateness of any method of separation. A legal/jurisdictional situation may exist for example which simplifies and clarifies questions of air rights so that skyway systems become less complicated from this point of view. Similarly, special service system infrastructure conditions can exist which may either exclude or make more feasible certain separation methods. In these cases, allowance has been made in the matrix for such specific conditions to be entered and for the appropriate judgements on methods of separation to be made against these conditions and new values entered which may or may not supersede those generic values that are assigned.

18-19. Climate Protection through Enclosure or Shelter

Three aspects of the climate in an area may warrant the installation of a complete enclosure or a shelter for a walkway - high winds, extremely hot or cold temperatures, and precipitation. Complete enclosure can only be provided on three types of separation systems -

- right-of-way within a site or building
- tunnels or subways
- elevated walkways

Shelter systems have a much broader application since they can be used on all separation methods, except for the temporary street closing.

Shelter systems, while not insulating the pedestrian from extreme temperatures, provide protection from snow, rain, sleet and the direct heat of the sun. A method for baffling winds can also be incorporated into the design of the shelter system.

20-21. Topography, Flat or Sloped

One of the inherent disadvantages of vertically separated systems is the requirement that the pedestrian must exert energy to change from one level to another. On flat terrain this is accomplished by stairs, escalators or elevators. Previous studies have shown, however, that pedestrians tend to continue on the same level, even if obstacles are confronted. On flat terrain thus, horizontally separated walkway systems tend to be more efficient.

Sloping ground conditions create natural springboards from which vertically separated walkways can be installed.

Topographic changes which permit access to above or below grade walkways as a continuation of a grade level path reinforce the pedestrian's natural tendency.

Grade separated walkways that are independent of building structures will most easily be able to respond to topographic change.

22-25. Activity Abutting Pathway

This refers to the existing land uses that are assumed to be adjacent to a pathway under consideration. Four categories of land use activity are matched against methods of P/V separation - retailing, office, entertainment/social/recreation and residential. Their characteristics in relation to various methods are discussed in turn:

Retailing ideally requires continuity and allowance for the shopper to cross freely and without conflict between stores located opposite each other. Full malls and R.O.W.s within sites or buildings allow these types of movement without encumbrance. Partial malls enhance and sidewalks allow of the continuity aspect, but still entail a crossing conflict. With the introduction of midblock crossings the crossing conflict is reduced.

Retailing is most successful where grade transitions are non-existent or if they exist, require minimum energy expenditure and time delay. Above-grade elements and vertical connectors are scored to reflect this principle. Where, with above grade elements, the abutting land use 'platform' is more integrated with the walkway platform, there is more potential for varying walkway width and attributes to suit existing adjacent conditions. Below grade land use activity already implies than an access pathway exists and thus the issue of selecting the appropriate method of separation cannot apply here.

Considerations similar to retailing are appropriate in considering recreation-cultural-social-entertainment facilities or districts. One different in this context can be an increased single destination orientation on the part of visitors to the area. For example, many persons will tend to go directly to and from an event, such as a concert or sporting match without walking to any other activity. Moreover, events, since they start and end at appointed times, create extreme peak pedestrian volumes. The magnitude and frequency of these volumes will determine the degree to which these special events require special considerations.

The conditions under which pedestrian-vehicular separation systems can serve office land use activities are different from those for either retailing or entertainment social/recreational type activities. Here pedestrian flows peak sharply at A.M. arrival, P.M. departure and lunch times. A full mall facility under these conditions is not warranted. Widened sidewalks, partial malls, and particularly arcades (setbacks) along appropriate stretches can be justified if the volumes of pedestrians exceed the existing sidewalk right-of-way.

Independent above grade methods of separation can be justified in given situations since these elements can be among the most direct linkages between origins and destinations and pathway directness is of major importance for work trips.

Pedestrian movement within residential areas is rarely sufficiently aggregate to warrant methods of p/v separation more extensive than partial malls (widened sidewalks). In residential environments, however, considerations of safety are more significant than where other land use activities are concerned. Studies have indicated that urban ped/veh accidents are highest at the interface of urban residential areas. Pedestrian pathways separate from vehicle rights-of-way are justified for this reason as are temporary or phased street closings which create play streets for children. For a similar reason grade separation methods are justifiable. Independent above grade elements tend to be most suitable since they respect the social needs for privacy and territoriality that are associated with residential communities. Below grade elements are unsuitable because of the high security risks associated with them.

26. Legal/Jurisdictional Factors

Questions of propriety, legal enactments, and political structures will affect the feasibility of different methods of separation.

From this standpoint, the most feasible methods of separation will be those that generally

(1) involve a minimum change of the status quo
(2) entail minimal coordination between different jurisdictional authorities
(3) require minimal acquisition of property or new right-of-way
(4) are entirely within the private domain

Above and below grade methods of separation usually tend to violate some or all of the above desiderata the most, while time displacement methods tend to violate them the least.

Legal/jurisdictional climates may vary substantially from the norm in a given locale. Legislation might allow for example, of a quick-take action for public acquisition purposes, or legal issues regarding air rights might have been resolved and incorporated into existing ordinances, etc. Blank column headings have been left in the matrix for any such special conditions to be noted and for the appropriate judgements on methods of separation to be made against them.

Depending upon the nature and comprehensiveness of the conditions that are entered, the assigned generic values may be superseded and thus not be included in the evaluation procedure. In most cases, however, they will be retained together with any additions.

27. Infrastructure

Public utilities infrastructures - sanitary and storm sewers, water distribution pipes, power and communication lines, steam and natural gas pipes, etc. - are invariably found under the public rights-of-way within the central business districts. In addition, there may be tunnels - railroad, subway, connections between adjacent buildings, etc. - under some of the rights-of-way. In older cities, basements may protrude into the underground space below the street and sidewalk surface.

Pedestrian facilities that require subsurface work - footings for skyway systems or more seriously, tunnels for subwalks - may incur extremely high costs in the relocation of infrastructural system elements. In general, those pedestrian methods of separation that deal with surface treatments only or do not impinge on the public rights-of-way will have the least impact on subsurface infrastructure.

The concentration and significance of infrastructural systems will vary considerably from site to site. Costs associated with excavation for utilities relocation, for example, can contribute an additional 30 percent to 200 percent to base construction costs. Where special infrastructural situations exist which modify the values assigned to the different methods of separation, these are to be entered in the blank column headings provided in the Matrix and new values entered. Depending upon the nature of the situation the assigned generic values may be either superseded or retained.

28. Non-Functional Space

Non-functional space is defined as any one of the following conditions:

(1) An existing vehicular right-of-way that is unnecessary to the functioning of the vehicular circulation network.
(2) A vehicular right-of-way that is considerably underutilized in terms of its available right-of-way.
(3) Vacant sites.
(4) Functionally obsolete land uses or structures.

Non-functional space yields opportunities for the installation of ped facilities that are at grade level. Full malls, temporary or phased street closings and partial malls will most commonly be the viable method of separation employed in the exploitation of non-functional space.

29. Existing Land Use Interface

A major factor influencing the selection of appropriate methods of separation is their need to interface with existing land use conditions.

Clearly those methods of separation that physically or functionally impact existing structures the least, will be the easiest to implement from numerous points of view. The scoring of the matrix under "Existing Land Use Interface" is based on this understanding and the doubled weighting values reflected the importance of this site constraint.

30-32.Future Land Uses

In the same sense that existing land uses influence the choice of methods of separation, so too future land uses through their disposition and location, are powerful determinants in the selection of separation methods.

At grade (horizontal separation), above grade or below grade methods of separation will be either directly relevant or meaningless when matched against at grade, above grade or below grade future land uses. The double weighting of scores reflects the significance of this factor in the selection procedure.

Where future land uses have not been articulated in any detail, a particular method of ped/veh separation that may be desirable for other reasons (e.g., topography, modal interface, imagibility, existing land uses, etc.) can become a shaping factor in the design and disposition of future land uses. Through this early integration of ped systems with future land use planning, major negative phasing and cost impacts associated with a given method of separation (particularly vertically separated methods) can be resolved or minimized.

33. No Available Right-of-Way

This column heading refers to a condition where no horizontal right-of-way beyond the existing sidewalk is available for use by pedestrians. This situation would arise where additional space for pedestrians is needed but vehicles require the entire street R.O.W. for circulation/service access or parking.

Assuming that traffic and transit management plans are unable to provide the needed pedestrian R.O.W., then the only possible methods of acquiring it are

(1) the creation of setbacks at the building line
(2) vertical methods of separation
(3) temporary or phased street closings.

Since the non-availability of right-of-way is a major factor in determining the choice among methods of separation, its associated weights in the matrix have been doubled.

SUPPLEMENT 14

DEFINITIONS OF DESIGN TREATMENT TYPOLOGY

The following definitions elaborate on Table 46.

14.1 Traffic Control Devices

The fundamental intent of traffic control elements is to facilitate safe vehicular movement and alleviate pedestrian/vehicular conflicts. The methods within which various elements are used fall under two general classifications.

A. Regulation of Vehicular Movement Characteristics such as:

- Locational and dimensional aspects of vehicular R.O.W. and its relationship to pedestrian pathways
- Access and type of vehicular use
- Volume of vehicular traffic
- Speed along R.O.W. and movement at intersections and cross streets
- Direction and channelization of flow

B. Increased Driver Awareness such as:

- Caution driver when there is the need for more than ordinary operating care
- Provision of guidance and directional information

Subcategories of traffic control devices

1. Traffic Signalization/Phasing - control devices utilized to manage traffic and pedestrians by means of time separation at high demand, extremely hazardous, or complex intersections. Includes fixed time and special signal actuation or phase extension installations.

2. Regulatory Signs - principally used to govern movement, parking, etc., and include:

   - Stop and Yield Signs - intended to reduce conflicts between crossing vehicles or used with respect to pedestrians to assign street priority or assign sequential right-of-way.

   - Directional - including "Do Not Enter" and "One Way" signs intended to inform the motorist that the entrance to the roadway is restricted or prohibited.

- Use Restrictions - intended to limit roadway use for such purposes as loading or parking.

- Speed Limit Signs - intended to inform drivers of the safe legal limits along the street network.

- Turning Prohibitions - used in advance of intersections where turns are prohibited.

3. Movement Control Devices - elements used to govern traffic flow.

   - Chokers - the practice of physically narrowing the street to enhance, for example, pedestrian crossings at intersections and improve sight distance for both the pedestrians and motorists.

   - Traffic Circles - this treatment places a small traffic circle in the middle of an existing intersection to provide a device less restrictive than a diverter yet reduces the volume and speed of traffic in the area.

   - Diverter/Semi-Diverter - a diverter is a form of traffic barrier most typically employed to impose a curvilineal or indirect street pattern on a rectangular grid. It is used to prevent movement straight through an intersection by means of deployment diagonally across the intersection. A semi-diverter is a physical barrier which allows travel in one direction while prohibiting travel in the other direction. It is most often placed close to an intersection to prohibit vehicles entering the street.

   - Speed Bumps - used to reduce speed along minor streets and parking lots.

   - Chatter Strips - intended to alert the motorist to special traffic conditions ahead requiring the reduction of speed such as pedestrian crosswalks.

4. Right-Of-Way Controls - treatments principally affecting the configuration and alignment of the vehicular right-of-way to restrict or increase traffic volume or flow for the purpose of improving both vehicular and pedestrian safety and movement.

   - Off Set Street Alignments - intended to minimize vehicular/pedestrian conflicts in predominantly pedestrianized areas by discouraging the incursion of heavy vehicular through traffic.

- Narrow Right-of-Way - intended to facilitate safer pedestrian movement adjacent to the R.O.W. reduce vehicular traffic capacity and enhance visibility for both the motorist and pedestrian.

- Serpentine Street Alignments - intended to safely accommodate the development of pedestrian activity nodes next to the vehicular R.O.W. and at existing strategic points such as entrances to theaters, public buildings, major department stores, and major office buildings.

- Channelization (intersections) - intended to control the flow of traffic at intersections and provide space within the roadway to safely accommodate pedestrians who are unable to cross in single movement.

- Narrowing Entrances (necking down) - may be employed to discourage access to minor streets from major R.O.W.s. The reduced street width may be used to improve pedestrian crossing by creating an extended vantage point from which pedestrians view traffic. It may also be used to provide a location for traffic signs closer to the driver's normal line of sight and where obstructions are less likely to occur. In addition, it may facilitate the closing of streets for special events or for temporary malls.

- Median Barriers and Guard Rails - traffic separators intended to restrict R.O.W. access and prevent vehicles accidentally leaving the roadway from colliding with roadside obstacles and pedestrians. May also be used to mask out approaching headlights at night and contain light sources with low elevation glareless illumination.

14.2 Pedestrian Movement Constraints

These treatments are used almost entirely to enhance pedestrian safety through:

A. Controlling and channelizing pedestrian movement
B. Facilitating pedestrian movement and,
C. Increasing pedestrian awareness.

Subcategories of pedestrian countermeasures

1. Marked Crosswalks (intersection and midblock)

Painted or paved crosswalk markings are typically used to delineate pedestrian pathways across streets. They are intended, when used without traffic signal control, to provide pedestrians with opportunities to cross vehicular R.O.W.s and to alert drivers to the possible danger of pedestrians with the R.O.W.

2. Demand Actuated Signals

These are intended to facilitate pedestrian crossings at intersections and at midblock. Actuation of the signals will cause the signal to stop traffic on the roadway or modify the duration of the signal interval to allow sufficient time for pedestrians to cross the roadway.

3. Right-of-Way Controls

The function of these treatments is to restrict pedestrian movement, to well defined and safe pathways.

- Medians and Safety Islands - these are intended to protect pedestrians from vehicles accidentally leaving the roadway and to provide a defined space within the roadway to safely hold pedestrians unable to cross in a single movement or within a traffic light time phase.

- Channelization/Barriers - (including bollards, fencing, and landscaping) - intent of these countermeasures is principally to direct pedestrian movement and restrict incursion into vehicle roadways.

- Curbs (level change) - defines the interface between vehicular and pedestrian systems. Provides a warning to the pedestrian, who is accustomed to the vehicle-free environment of the pedestrian pathways that he is approaching a vehicular dominated zone.

4. Pedestrian Control Devices

These are intended principally to promote safety through increased pedestrian awareness.

- Regulatory signs (including: walk-don't walk, directional and warning) - these devices are frequently used to exclude pedestrians from areas considered to be unsafe or where their intrusion will inhibit vehicular movement. Prohibitive signing is employed to direct pedestrians to alternate crossing locations and to restrict their use of particular areas

- Lighting - intended to delineate routes of travel and provide level of safety and security in the dark.

- Paving (texture and color) - in functional terms it can be used, by means of changing the paving character, for orientation and warning along pedestrian and vehicular pathways and at intersections. It can be further used to articulate special use areas such as drop-off points, loading areas and no parking zones.

14.3 Vertical Connectors

The function of these elements is to link grade separated pedestrian pathway or destinations.

Subcategories of vertical connectors

1. Stairs
2. Ramps
3. Escalators
4. Elevators

14.4 Signage

Those visual-graphic aids which communicate trip making information for one of two basic purposes.

A. Wayfinding - this includes elements that enhance "orientation" within the movement area and along the pedestrian network. Also included are those elements that provide "direction" to major activity centers and indicate the most accessible or direct route.

B. Announcements - elements that provide "trip attracting" information such as directories or calendars of events and attractions.

Signage elements are further defined by their physical characteristics.

C. Overhead/Face of Building - elements located either parallel or perpendicular to the pathway whose support does not intrude into the pathway surface.

D. Freestanding - discrete elements whose supporting devices are located within the pathway.

Subcategories of signage

1. Wayfinding/overhead
2. Wayfinding/freestanding
3. Announcements/overhead
4. Announcements/freestanding

14.5 Lighting

The fundamental function of lighting is to provide safety and security for movement where and when natural light is inadequate.

Subcategories of lighting

1. Pedestrian Related Lighting - generally of smaller scale, lower intensity and frequent spacing.

2. Vehicular Related Lighting - generally of larger scale, higher intensity and less frequent spacing.

14.6 Street Furniture

Function of street furniture is to provide both pedestrian pathway convenience, amenity and attractiveness to complement trip making.

Subcategories of street furniture

1. Pedestrian Conveniences - those elements intended to add to pedestrian comfort.

   - Bus shelters
   - Marquees/canopys
   - Newsstands
   - Mail boxes, trash receptacles, vending machines, telephones and drinking fountains
   - Public restroom facilities
   - Benches/seating

2. Pedestrian Amenities - those elements intended to add to the pleasantness or attractiveness of the environment.

   - Paving (texture/color)
   - Lighting
   - Fountains
   - Sculpture
   - Kiosks (including display/sales)
   - Landscaping/planting
   - Play facilities
   - Street graphics (including art murals, etc.)

14.7 Landscaping

Planting elements including trees, shrubs, and grass utilized for the purpose of:

A. Sheltering
B. Screening of pedestrian and vehicular traffic, noise and blight
C. Visual accent or linkage
D. Channelizing pedestrian flow
E. Sun and weather protection

Subcategories

1. Large trees - including canopy trees and some evergreens where foliage starts generally higher than five feet above the ground.

2. Low plants - trees and shrubs with foliage below five feet

3. Non-grade Plantings - ground cover used in fixed planters and containers.

SUPPLEMENT 15

INTERSECTION DESIGN TREATMENTS

15.1 At-Grade Signalized Crossings

In most CBD areas at-grade signalized crossings located at the intersection of walkways and streets is the dominant feature of the pedestrian movement system. This system of intersections creates a level of discontinuity for both vehicular flow and pedestrian movement. The resulting conflict is among the most substantial of all factors which impact upon pedestrian safety, accessibility, and trip time. The following headings can be used to categorize the types of problems that occur at intersections:

- Accidents
- Vehicular Delays (stopping and turning movements)
- Pedestrian Delays
- Separation of Movements
- Congestion
- Physical impedance (due to improper placement of street furniture, landscaping, driveways, transit stop locations, etc.)
- Attention conflicts

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

- Street width and type
- The provision of measures to channelize and direct vehicular and pedestrian flow
- Pedestrian walking speed
- Pedestrian perception of risk-taking
- Volume of pedestrians
- Type of signalized controls
- Vehicle and pedestrian flow characteristics

Delays to users of an intersection is a problem that in many cases cannot be avoided (short of vertical separation) because of the very nature of the physical movement network in cities. However, minimizing delay and lowering the propensity for pedestrian/vehicular conflict can be achieved by consolidation of pedestrian pathways and reducing the number of vehicular street crossings per trip.

15.2 At-Grade Intersection Prototypes

Three types of pedestrian intersections and street crossings are described below and are prototypical in their application to the crossing situations that occur along major pedestrian networks. These prototypes relate to three specific conditions:

- Vehicular Street/Vehicular Street Intersection - the signalized crossing of two vehicular streets.
- Vehicular Street/Pedestrian Mall Intersection - the signalized crossing of a vehicular street with an exclusively pedestrian mall/street.
- Bus Transitway/Pedestrian Crossing - the midblock pedestrian crossing of a bus street.

15.2.1 Vehicular Street - Vehicular Street Intersection

This type of intersection utilizes a system of signalized crosswalks and devices to channelize pedestrian flow as illustrated in Figure 15-1. The pedestrian queuing space at each corner of the intersection is constructed of a distinctively textured concrete which provides a visual and tactile signal to the pedestrian that the nature of the pathway will change as a function of the approaching intersection conflict. Each queuing area is separated from the crosswalk by a typical curb detail. This curb is cut by a short ramp contoured into the sidewalk to provide access for the elderly and handicapped. The crosswalk markings consist of bright colored, bold stripes which are either applied to or set in the street paving.

The incorporation of channelization devices at intersections is recommended at those points where high volumes of pedestrian movement conflict with vehicles. These devices are particularly appropriate at intersection crossings where pedestrians may attempt to leave the sidewalk prior to the provided crosswalk. A short segment of bollards or the placement of street furniture elements can be used to impede their movement. A module could be developed for the purpose of consolidating a variety of presently existing street furniture elements such as newspaper vending, trash bins, mail boxes, etc.

The location of the modules should be clear of the desired flow of pedestrian traffic through the intersection as shown in Figure 15-1.

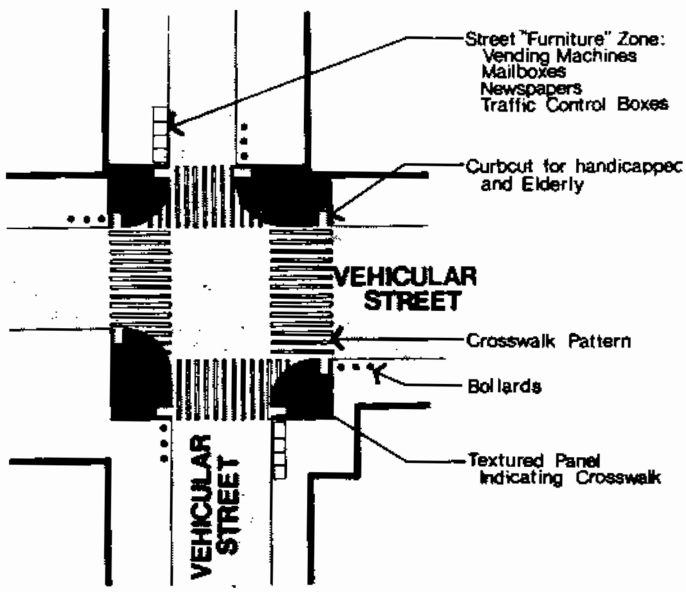


FIGURE 15-1

Intersection - Vehicular Street And Vehicular Street

15.2.2 Vehicular Street - Pedestrian Mall Intersection

This intersection type utilizes a Barnes' Dance (All Walk) Signalized crosswalk and additional pedestrian control devices as illustrated in Figure 15-2. The physical features of this intersection treatment are intended to alert the pedestrian who is accustomed to the vehicular-free environment of the pedestrian mall that he is approaching a vehicular intersection. The paving material of the mall should not extend across the vehicular street, as the consistency of the paving pattern is misguiding to the pedestrian. The pattern, in terms of mixture and color, should be changed to provide a visual and tactile message to the pedestrian of the impending crossing conflict. Additionally, distinctive bollards should be used to provide a vertical element visually separating the exclusive pedestrian mall from the intersecting vehicular street. In addition, vehicular traffic should be alerted to all major pedestrian crossings by the use of chatter strip type panel set in the street in proximity to the pedestrian crosswalk area.

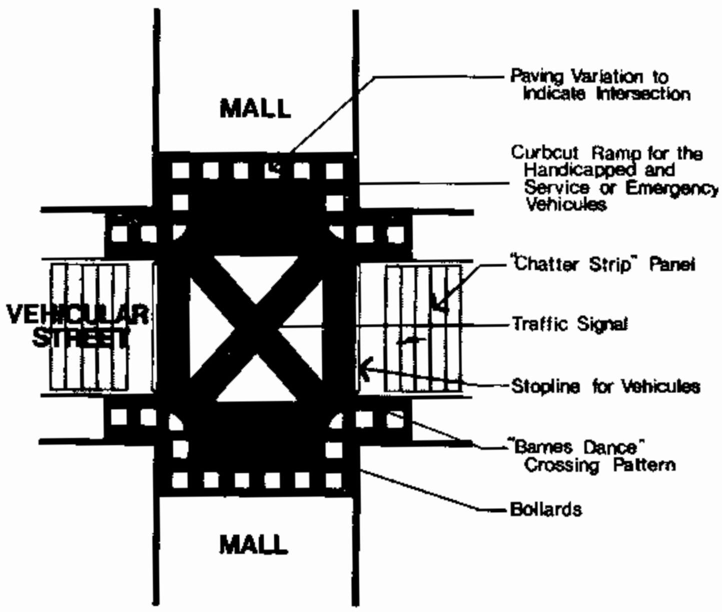


FIGURE 15-2

Intersection - Vehicular Street And Pedestrian Mall

15.2.3 Bus Transitway - Pedestrian Crossing

This prototypical midblock pedestrian crossing (see Figure 15-3) is suitable only along bus transitway streets. Generally the crossings are unsignalized due to the ease of crossing a two-lane bus street. They provide increased accessibility to activities along each segment of the transitway. Curb cuts for handicapped pedestrians and a bold strip crosswalk pattern is utilized to further delineate these midblock crossings. A textured panel, similar to that utilized at corner crosswalks, extends into the sidewalk right-of-way to alert the pedestrian to the crossing opportunity.

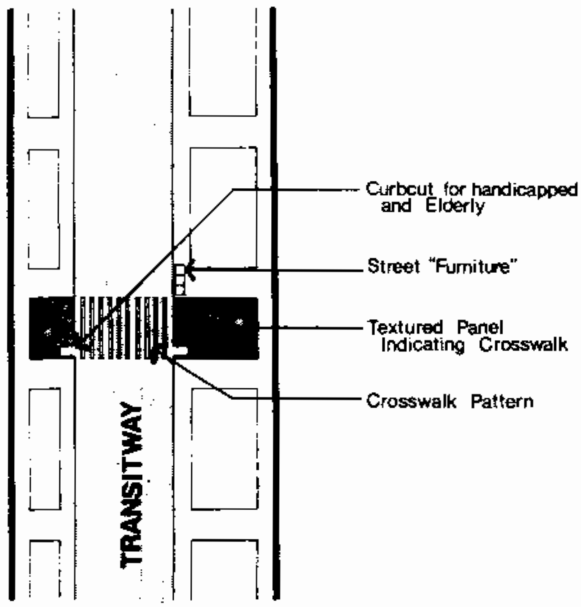


FIGURE 15-3

Intersection - Bus Transitway And Pedestrian Crossing

15.3 Pedestrian Signal Phasing

The pedestrian signals at the intersection consist of a combination of WALK and DON'T WALK indicators. At appropriate locations Barnes' Dance (All Walk) phases are employed to accommodate high pedestrian volumes and eliminate conflicts between pedestrians and turning vehicles. Pedestrian-actuated push buttons are also utilized at specific locations to indicate that a pedestrian demand exists at that crossing point.

The timing of the pedestrian signal phase is normally determined as a function of the green time allocated to vehicular movement. The walk time is calculated as the vehicular green time minus the time required for crossing the traffic right-of-way using a walking speed of four feet per second. The ALL WALK pedestrian phases are determined similarly, with the crossing time calculated for the movement diagonally across the intersection. For typical green times and street widths, the resultant 20 to 40-second pedestrian signal phase is usually adequate. However, this signal phase is not adequate during inclement weather and when considering the requirements of the handicapped and the elderly. Under these conditions a 20 second pedestrian phase will not be sufficient to allow pedestrians to complete the crossing. To accommodate for all situations, it is recommended that a minimum pedestrian signal of 30 seconds be established for the major crossings occurring within the Pedestrian Network Plan. This will further encourage pedestrian utilization of the Network and consolidate pedestrian movement away from other traffic intersections.

SUPPLEMENT 16

IMPACT ASSESSMENT METHODOLOGY - CALCULATION OF BENEFITS

16.1 Preamble

The supplement consists of selected portions* from an evaluation study entitled Quantifying Benefits of Separating Pedestrians and Vehicles**. The authors of this study explicitly invite modifications to their evaluation criteria and the suggested weights associated with these as well as the scoring techniques for evaluating the variables. This Manual recommends modification to the criteria (by way of selective abridgement) and a different weighting system based on research and experience accumulated in developing the PPP. Figure 13A illustrates these changes. (Compare with Figure 13). The scoring techniques are not modified. The methodology of the original study is entirely usable within these modifications. The effect of the modifications is to speed and focus the determination of benefits. The user who has the resources for the comprehensive evaluation proposed by the original study may refer to that document.

16.2 Suggested Evaluated Methodology

The research objective was to develop a comprehensive evaluation methodology that could be used to assess individual and alternative proposals for pedestrian separation facilities. The method developed is a unitless scoring system that combines subjective values reflecting community preferences with objective measurements for each of the 36 variables in Figure 1. Measured variable scores are weighted by preference or relative importance multipliers before the resulting relative benefit values for each variable are incorporated into a total score for each facility. This combination provides much more than just a "score" for a proposed facility, because the weighted variable scores provide considerable insight both on the values of the decision-makers, and on the attributes of the facilities themselves. This added information supports a careful comparison of alternative proposals by identifying the important differences between alternatives. Chapter Two contains a detailed description of the characteristics of the evaluation methodology developed during this reseaarch.

Because many of the variables are subjective in nature (e.g., comfort, attractiveness, noise), the measurement of benefits is performed using a unitless scale of positive and negative values (+10 to -10) for

*For this reason the Figure and Table numbers in the supplement will not be sequential. Similarly text references will be found to chapters or Figures that have been omitted.
**NCHRP Report #189, Transportation Research Board, Washington, D.C. Publication scheduled for August, 1978.

1. TRANSPORTATION

1.1 Pedestrian

1.1.1 Travel Time
1.1.2 Ease of Walking
1.1.3 Convenience (Access and Availability)
1.1.4 Special Provisions for Various Groups

1.2 Motor Vehicles

1.2.1 Motor Vehicle Travel Costs
1.2.2 Use of Automobiles
1.2.3 Signal/Signing Needs Adjacent to Facility

1.3 Other Community Transportation

1.3.1 Adaptability to Future Transportation Development Plans
1.3.2 Impact on Use of Existing Transportation Systems

2. SAFETY/ENVIRONMENT/HEALTH

2.1 Safety

2.1.1 Societal Cost of Accidents
2.1.2 Accident Threat Concern
2.1.3 Crime Concern
2.1.4 Emergency Access/Medical and Fire Facilities

2.2 Attractiveness of Surroundings

2.2.1 Pedestrian Oriented Environment
2.2.2 Litter Control
2.2.3 Density
2.2.4 Climate Control and Weather Protection

2.3 Environment/Health

2.3.1 Effects of Air Pollution
2.3.2 Noise Impacts of Motor Vehicles
2.3.3 Health Effects of Walking (exercise, fatigue, etc.)
2.3.4 Conservation of Resources

3. RESIDENTIAL/BUSINESS

3.1 Residential Neighborhoods

3.1.1 Residential Dislocation
3.1.2 Community Pride, Cohesiveness, and Social Interaction
3.1.3 Aesthetic Impact, and Compatibility with Neighborhood

3.2 Commercial/Industrial Districts

3.2.1 Gross Retail Sales
3.2.2 Displacement or Renovation Required or Encouraged by Facility
3.2.3 Ease of Deliveries and Employee Commuting
3.2.4 Attractiveness of Area to Business

4. GOVERNMENT AND INSTITUTIONS

4.1 Transportation and Land Use Planning Process

4.1.1 Public Participation in the Planning Process
4.1.2 Conformance with Requirements and Regulations

4.2 Economic Impacts

4.2.1 Net Change in Tax Receipts and Other Revenue
4.2.2 Resulting Changes in Employment
4.2.3 Change in the Cost of Providing Community Services

4.3 Community Impacts

4.3.1 Community Activities
4.3.2 Adaptability to Future Urban Development Plans
4.3.3 Construction Period

SA-3677-39

FIGURE 1

PEDESTRIAN FACILITY EVALUATION VARIABLES each variable. Positive values correspond to desirable characteristics, and negative values indicate undesirable characteristics. Zero values indicate either "does not apply" or "indifference" (neither good nor bad).

Unitless scoring reduces the need for assigning dollar values to the many noneconomic impacts of pedestrian facilities (and many other public projects). Such scoring is particularly appropriate to the stated project objective because comparison of alternatives can be performed by comparing unitless scores and costs without the need for calculating benefits in dollars. Guidance is also provided for obtaining benefit values in dollars, if required, to allow comparison of pedestrian facilities with other public projects.

The difficulties associated with the development of community preferences have been partially alleviated by the provision of suggested weights for each variable. The researchers devoted considerable effort to discussions with planners, analysts, designers, evaluators, decision-makers, and pedestrians to obtain information about their needs and desires, their likes and their dislikes concerning pedestrian environments. A questionnaire was also distributed to a similar but larger group of planners and decision-makers to obtain their relative preference values for each of the evaluation variables.

Different sets of weights may be appropriate for different types of pedestrian facilities, depending upon the major purpose of the facility. The safety/movement type includes those facilities where severe pedestrian/vehicle conflicts occur or where high pedestrian volumes result.

16.3 Discussion of Measurement Techniques

As the focal point of this research project, great care was taken in the selection of evaluation variables and in the development of specific measurement techniques for each variable. It soon became apparent that well-developed measurement techniques appropriate to pedestrian facilities were not available for most of the selected variables. Thus what had been planned as a moderate effort to choose and adapt appropriate techniques became a major development effort.

The previous section described the choice of a unitless scoring system for variable measurements. A scoring technique was developed for each variable ranging from +10 to -10. The maximum positive (desirable) score is +10, a neutral or does-not-apply score is 0, and the largest negative (undesirable) score is -10. Several basic techniques were used to develop a scoring system for each of the selected 36 variables. These basic tehniques are described in the following pages and illustrated with examples from Appendix A.

16.3.1 Types of Measurement Techniques Used

Selection of Value from Table. When this technique is used, the score for the variable is obtained by performing some measurement or observation, and looking in a table for the corresponding score. For example,

Number of Persons per 7'10" Square Box	Amount of Space (Square feet* per person)	Level of Service	Score
6 or more	10 or less	Measurable delay numerous conflicts	-10
5	12	Crowded	-6
4	15		-4
3	20	Constrained	0
2	30		4
1	60	Impeded	7
1/2	120		9
1/3	180	Free flow	10
Fewer than 1/23	1400 or more	Empty	6

*To convert square feet to square meters, multiply by 0.0929.

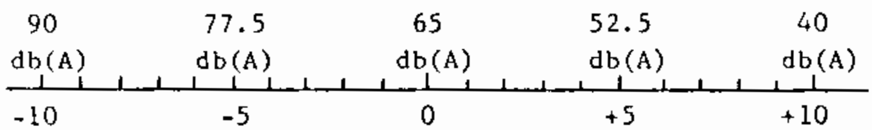
TABLE 2

PEDESTRIAN DENSITY AND LEVEL OF SERVICE

Pedestrian Density (2.2.3) is scored by determining the average amount of space available for each pedestrian, then looking up the corresponding score in Table 2.

In this case, a practical guide is also given for determining the amount of space per pedestrian. An area can be marked off or may already be available (e.g., concrete pavement separators). Then the number of pedestrians per block can be observed--the sample box given is about 8 feet (2.5 meters) square--and the corresponding values can be obtained.

Simple Formula. This scoring technique is illustrated by Noise Impacts of Motor Vehicles (2.3.2). In this case, both a formula (1) and a corresponding graphic scale (Figure 4) are shown for value selection. The appropriate score value is selected after a series of sound readings have been taken and averaged for the facility under evaluation (or estimated for proposed facilities).



Any noise level over 90 db(A) scores -10
Any noise level under 40 db(A) scores +10

$$\text{Total NOISE SCORE} = -10 + \left[(90 - \text{observed or estimated noise level}) \times 0.4\right] = \_\_\_\_\_\_ \quad (1)$$

FIGURE 4

Noise Level Scoring

This example also illustrates an important measurement feature, the setting of practical end points. Sound levels below 40 db(a) are not often encountered. Because values below this level would not be of added worth to users, a maximum score of +10 is used for all values less than or equal to 40 db(A). Sound levels above 90 db(A) make speech unintelligible and are actually hazardous to health. Therefore, the most undesirable score (-10) is assigned for any sound level greater than or equal to 90 db(a). Assigning practical end points has three valuable characteristics:

- The resulting smaller range of values allows greater sensitivity in the scoring of different facilities.
- More uniform scoring is frequently made possible because unusual characteristics often appear at the ends of a scale rather than in the middle.

The occurrence of values beyond the suggested end points alerts the evaluator to unusual conditions that may require special consideration on the part of planners or decision-makers (this situation is noted where appropriate in Appendix A).

Summed Table Values. Figure 5 illustrates the scoring technique used for Accident Threat Concern (2.1.2). This variable appears in the measurement techniques in addition to an accident variable (2.1.1) because utilization of a pedestrian facility is affected both by its actual accident history and by the apparent or perceived threat of accidents. Scoring for this variable is done by checking or circling the value that applies for each component listed in the left-hand column. The value selected may be positive, average, or negative. After a value is selected for each component, the positive and negative columns are respectively added as indicated. The total score is obtained by subtracting the negative sum from the positive sum.

		Positive		Average		Negative	
Vehicles	Traffic Volume	Low	2	Med	0	High	2
	Traffic Speed	Low	2	Med	0	High	2
	Turning Conflicts	Few	1	Mod	0	Many	1
	One-way Traffic	Yes	1	No	0		--
	Vehicle Mix		--	Mixed	0	High % Trucks Buses	1
Setting	Crosswalks	Marked	1		--	Unmarked	1
	Signalization	Veh and Ped	1	Veh Only	0	None	1
	Sight Distance	Good	1	Mod	0	Poor	1
	Lighting	Good	1	Mod	0	Poor	1

Sum the column values: Positive = ____ Average = 0 Negative = ____

Total ACCIDENT THREAT SCORE is Positive Sum - Negative Sum = ________

Med = Medium
Mod = Moderate
Ped = Pedestrian
Veh = Vehicle

FIGURE 5

Accident Threat Concern Scoring

Another measurement feature is illustrated by this example. Note that the components "Traffic Volume" and "Traffic Speed" are more heavily weighted (two times more) than any other component. This feature is used to indicate the relative importance of each component when some have a greater effect than others. In this example, up to 40% of the sum of the positive points (or negative points) can be contributed by the two named components, while the other seven combined can contribute only 60% of the respective sums. This weighting indicates the relatively strong effects of vehicle volumes and speed on fear of accidents.

Separately Scored Components. Some variables, such as Ease of Walking (1.1.2), have components with enough special characteristics that each component is separately measured. The scoring range for each component is established separately, then they are combined to produce a total score for the variable being evaluated. The listing below illustrates the individual range of values possible for the five components that together are used to score Ease of Walking. Similar to the previous example, different component scores indicate the relative weight of each of the components within the variable.

	Scoring Range
Walking surface	-2 to 2
Grade changes	-4 to 2
Continuity	-1 to 2
Signing	-1 to 2
Lighting	-2 to 2
Total EASE OF WALKING SCORE	-10 to 10

Weighted Formula. Complex variables such as Societal Cost of Accidents (2.1.1) and Travel Time (1.1.1) make use of a type of formula that can be adjusted (or weighted) to comparatively measure several facilities. The formula effectively lowers the possible scoring range for each facility proportionately to the magnitude of a selected scaling parameter. For example, formula (2) below is used to score the cost of accidents.

In the above formula, the numerator represents the difference between the number of accidents before the proposed facility (present), and after the proposed facility (proposed). The number of accidents for each case is obtained by multiplying the number of crossings by the NI Rate (Net Accident Involvement Rate), computed by using Figure A-9 in Appendix A. The feature being illustrated, however, is the denominator. By selecting the maximum number of accidents (either present or proposed), and dividing the difference in accidents for each individual site by this one number, the individual scores will be proportional to the number of accidents for each facility. For example, if Site A had a reduction of 10 accidents and Site B had a reduction of 5 accidents, the scoring for Site B would be only one-half of the score for Site A. If the denominator were 20, the score for A would be +5 and the score for B would be +2.5 (or rounded to +3). This type of formulation is required for some key variables to maintain a level of comparability for the scores of several facilities.

Qualitative Scoring. Some of the variables under consideration in this project were simply too subjective to devise reasonable quantitative measures. For such variables, discussion and some general guidelines appear in Appendix A. The evaluator is then required to assign a value based on judgment and the guidelines given, as illustrated in Figure 6 for Adaptability to Future Urban Development Plans (4.3.2).

-10	-5	0	+5	+10
Requires significant modifications to existing land use and development to accommodate the facility		No significant effect on short- or long-term land use and development plans		Enhances desired land use and growth patterns

FUTURE URBAN PLANS SCORE selected = __________.

FIGURE 6

Urban Plan Scoring

16.3.2 Criteria for Measurement Technique Selection

Several important criteria were used to guide the selection of a measurement type for each variable or component. The first was to choose the measurement type that provided the most precise degree of quantification consistent with the data and information available for the item under consideration. The examples given above indicate the approximate degree of quantification that could be used in a practical measurement technique for each of the sample variables. The second criterion was a deliberate attempt to measure at least one level deeper in precision that had been previously attempted by others. This criterion was adopted to encourage serious consideration by evaluators and others into the meaning and possible importance of all of the variables. The third criterion was an attempt to estimate the relative importance of components within variables, especially where the literature or discussions between the researchers and others indicated probable unequal weighting between components.

Many of the measurement techniques developed during this research project extend beyond the usual level of quantification for the selected variables. Thus, use of the developed measurement techniques and future research will verify some of our observations and will also require changes in others. We encourage the users of this research to make changes to specific measurement techniques whenever such changes seem appropriate. When somewhat different values seem more appropriate to particular groups of evaluators or decision-makers, they should be used. Our primary objective in the development of measurement techniques has been to develop a flexible, quantitative framework for examining and evaluating the many potential impacts of pedestrian facilities. Thus, the techniques will remain useful even if specific values for individual variables or components change over time.

16.3.3 Treatment of Costable Variables

Five of the 36 evaluation variables are costable; each of these first is expressed in dollar units and then scaled to the standard -10 to +10 range. The first of these and sometimes the largest in absolute magnitude is Motor Vehicle Travel Costs (1.2.1). Vehicle operating and ownership costs are combined with parking costs, and a dollar equivalent of travel time is also included. Total motor vehicle travel costs are transformed to the unitless +10 to -10 scale based on the change from the existing situation.

Two variables in the retail sector, Gross Retail Sales (3.2.1) and Displacement or Renovation Costs (3.2.2) are computed in dollars. Gross Retail Sales are translated to the unitless -10 to +10 scale based on their average annual percentage increase, and Displacement and Renovation Costs are transformed by expressing them as a fraction of the change in gross sales.

The last two costable variables are in the public sector; they are Tax Receipts and Other Revenue (4.2.1) and Cost of Providing Community Services (4.3.2). These are transformed to the unitless scale by dividing by the existing total city budget for the previous year.

Value of Pedestrian Travel Time. Two other variables, Pedestrian Travel Time (1.1.1) and Societal Costs of Accidents (2.1.1) are frequently translated into dollar costs in transportation studies, but this assignment requires judgments to be made of the value to society of an individual's time and the value of reducing accidents, particularly fatalities and serious injuries. This assignment of value is not required by the methodology, but the procedure for imputing values to each of these variables is described below for use by those who desire it.

By the same means that value can be established for savings in automobile travel time (by observing drivers' and passengers' willingness to pay for time savings by using a faster toll road), pedestrian travel may be evaluated by willingness to pay transit fares to save time. However, there are other factors involved in the pedestrian's decision to take transit, particularly comfort and a chance to sit down while traveling. Nevertheless, a few attempts have been made to quantify the value of pedestrian travel time based on willingness to pay transit fares and other models.

Contemporary investigators have concluded that motor vehicle travel time savings for commuter trips should be valued at approximately one-half the prevailing wage rate. Thomas (1968) used 0.5 of the hourly wage rate, Ellis (1972) used 0.5 and Webster (1974) used 0.55. Thomas and Thompson (1971) have shown that the value of travel time varies significantly with the magnitude of time saved per trip. Updated values of their findings presented in Andersen et al. (1975) indicate values of 6.4% of the wage rate for time savings of less than 5 minutes, 32.2% between 5 and 15 minutes, and 52.3% over 15 minutes.

One should assign a higher value to the travel time of pedestrians than that of passenger car occupants. This is because the motorist is in a climate-controlled environment, physically protected and psychologically insulated from the outside. The pedestrian, on the other hand, pays a higher price for travel because of being rained upon, splashed on, exposed to cold, threatened by accidents, and may suffer an invasion of his psychological buffer zone. The pedestrian is frequently a purchaser. All of the face-to-face business transacted in a city, except for a limited number of drive-in facilities, is conducted by pedestrians. Since he makes shorter trips than the motorist, a given delay will account for a larger fraction of his total trip, and thus causes more inconvenience. His time is at a different level of perception from that of the motorist and, therefore, has been valued by researchers at two or three times the rate for motorists. The listing below shows the values derived by various investigators.

Investigator	Date	Ratio of Pedestrian Travel Time Value to Motorist Travel Time Value
Quarmby	1967	2 to 3
Lisco	1968	2.8
Ellis	1972	2
Pushkarev and Zupan	1975	3.2
Dawson*	1975	2

*From personal correspondence.

The elderly, handicapped, young, and poor--because they often do not own automobiles--are likely to be overrepresented among pedestrians in suburban and rural locations. These people are often not employed and thus they probably assign a lower value than average to their time. Hence, a lower value of time could be used for locations other than central business districts. It is also more appropriate to express pedestrian travel time as a value per minute (than per hour as for passenger car time) because pedestrian trips are usually shorter. Even though the time saved is small compared to the total trip time, it is still perceptible to the pedestrian.

The low values associated with small travel time savings for motorists are related to the variability in motor vehicle travel time for a given trip, which is a function of traffic congestion, time of arrival at traffic lights, presence of law enforcement officers, weather, and the time required to find a parking space. Pedestrians, on the other hand, are more in control of their total travel time, since stops for rest, sightseeing, shopping, or conversation are usually discretionary. Only delays due to conflicts with vehicles and other pedestrians are usually beyond the control of the pedestrian. Information observation by project team members show that pedestrians are acutely aware of and quite irritated by even small delays, such as turning vehicles or escalator queues. Additional evidence is provided by the design guidelines for new elevator installations in office buildings, which frequently specify average waits of no more than 30 seconds and average travel times of no more than 60 to 90 seconds (Strakosch, 1967) at a considerable cost expense per elevator. Thus, even small changes in pedestrian travel time, particularly those caused by delays rather than changes in walking distance, should be appropriately valued in the methodology.

Considering all of the above and making the assumptions listed below, acceptable values have been developed for pedestrian travel time. The assumptions are as follows:

- The average wage rate is $6.00 per hour for pedestrians in a busy central business district (CBD) and $4.50 per hour for other pedestrians. Webster (1974) used $5.10. Although the national average wage rate for all private production and nonsupervisory nonagricultural workers was $4.49 in June 1975, a substantial fraction of pedestrians in the average CBD hold supervisory or professional positions at higher wage rates.

- Automobile travel time is valued at one-half the prevailing average wage rate, and pedestrian travel time is valued at two and one-half times the value for an automobile traveler, or one and one-fourth times the wage rate.

- The value to an employer of his employees' time is one and one-half times the wage rate. This takes into account fringe benefits, training costs, and profit or overhead.

- Delays of up to five minutes are valued at twice the average wage rate.

- Leisure travel and the time of limited mobility groups is valued at one-half the normal rate.

- Children under the age of 16 have a zero value of travel time, except when the travel decision is made by the parents, in which case, other trip characteristics (such as safety) may be more important than travel time.

When calculations are performed using the listed assumptions, the guidelines depicted in Table 3 are obtained. The reader is, of course, free to use other values, particularly to reflect the local economic conditions.

The total cost of pedestrian travel time is obtained by using the data summarized in Appendix A, page A-13. The total travel time (in minutes) for each pedestrian group is multiplied by the corresponding values from the table above, producing travel time costs for the existing situation and for a proposed facility.

TABLE 3

Values of Pedestrian Travel Time

Type of Pedestrian (or Trip)	Value of Time (per minute)	
	Central Business Districts	Other Locations
Commuters, workers on lunch break, or unknown mix	12¢	9¢
People in the course of their work	15¢	11¢
Delays (such as stop lights)	20¢	15¢
Other: Leisure trips, personal business, handicapped, retired, or students	6¢	6¢
Elementary school children	0	0

Societal Cost of Accidents. The approach taken to the evaluation of accident costs in this project is to estimate the total societal costs resulting, directly or indirectly, from motor vehicle accidents involving pedestrians. The monetary values presented here are based on the NHTSA study, Societal Costs of Motor Vehicle Accidents (U.S. DOT, 1972). When values from this study are updated to 1975 using a 6% cost increase per year, the average societal cost of a facility is estimated at $239,000; the average cost of a nonfatal injury (average of disabling and nondisabling) is estimated at $8,700. These values include: medical costs (doctors, medication, special services), legal and court costs, hospital costs, loss of income, employer losses, losses to others, funeral costs (for fatalities), cost of community services, pain and suffering, losses in assets, and insurance administration costs.

An examination of pedestrian accident statistics for 1974 from Accident Facts (1975) shows that there were 8,700 pedestrian fatalities in 1974 out of an estimated 300,000 pedestrian accidents (about 3 per 100). The same source lists 120,000 nonfatal pedestrian injuries (40 per 100) that were disabling beyond the day of the accident. However, this does not include nondisabling injuries. It is estimated that some personal injury results from almost all reported pedestrian/vehicle accidents. This conclusion is consistent with an intuitive observation on the probable result of an impact between a 150-pound (70-kg) person and a 4,000-pound (1,800-kg) vehicle. This estimate is also supported by other data in Accident Facts (1975) where 40% of the injuries in all types of accidents are classed as disabling, and 60% of the injuries are classed as nondisabling. Thus, the values shown in Table 4 are used in estimating the dollar cost of pedestrian accidents.

By combining the previously developed figures with an estimated probability of a pedestrian accident per person crossing in urban areas of 5×10^{-7} (Prokopy, 1974), an estimated societal pedestrian accident cost of 0.78 cents per person crossing is obtained. This combination provides an estimate of accident costs at an existing or planned pedestrian facility based on the number of pedestrians crossing vehicle lanes.

TABLE 4

Accident Frequency and Cost by Severity

<table>
<tr><th>Accident Severity</th><th>Frequency of Severity per Accident</th><th>Cost per Accident by Severity</th></tr>
<tr><td>Fatality</td><td>3 per 100</td><td>$239,000</td></tr>
<tr><td>Disabling injury</td><td>40 per 100</td><td rowspan="2">$ 8,700</td></tr>
<tr><td>Nondisabling injury</td><td>57 per 100</td></tr>
<tr><td>All</td><td>100 per 100</td><td>$ 15,600</td></tr>
</table>

Also note that complete vehicle/pedestrian separation will result in no such crossings, which will reduce the accident cost for such a facility to zero. Planners who are proposing facilities in an area with reliable historic accident experience data can use the previous data and scale it by the estimated number of pedestrian crossings in the proposed facility divided by the estimated number of pedestrian crossings during the corresponding accident data collection period.

A technique was developed to modify the basic pedestrian accident risk figure per crossing (5×10^{-7}) by considering several pedestrian, vehicle, environmental, and traffic control factors. The relative accident risk per crossing for each facility (or each crossing point within the facility if necessary) is developed using Figure 7, Accident Involvement Rate Adjustment. For each crossing to be analyzed (one representative crossing may be evaluated if several similar crossings are involved), check off the boxes that apply, then sum the results using the formula below the table under both present and planned conditions, obtaining Net Involvement Rates (NI Rate) for both situations.

After estimating the present and proposed number of pedestrian crossings per year, the following formulas can be used to obtain a dollar cost figure for each site alternative. Formula (3) can be used if reliable historic accident data are not available, and formula (4) or (5) can be used if such data are available.

$$\begin{aligned}\text{Annual Cost} &= \text{estimated number of annual accidents} \times \$15{,}600\\ &= \text{accident risk per crossing} \times \text{proposed no. of crossings} \times \$15{,}600\\ &= 5 \times 10^{-7} \times \text{proposed NI Rate} \times \text{proposed no. of crossings} \times \$15{,}600 \qquad (3)\end{aligned}$$

or

$$\begin{aligned}\text{Annual Cost} &= \text{historic accident risk per crossing} \times \text{proposed NI Rate} \times \text{proposed no. of crossings} \times \$15{,}600\\ &= \frac{\text{historic number of accidents}}{\text{historic no. of crossings} \times \text{historic NI Rate}} \times \text{proposed NI Rate} \times \text{proposed no. of crossings} \times \$15{,}600 \qquad (4)\\ &= \text{historic no. of accidents} \times \frac{\text{proposed NI Rate}}{\text{historic NI Rate}} \times \frac{\text{proposed no. of crossings}}{\text{historic number of crossings}} \times \$15{,}600 \qquad (5)\end{aligned}$$

The estimated accident cost savings of a proposed pedestrian facility equals the present accident cost minus the estimated accident cost of the proposed facility.

	Number of:	Rate Decreases				Average		Rate Increases			
PEDESTRIAN	Elderly (≥65)	Few	10	5%	5	10%	0	20%	20	>30%	40
	Very Young (≤10)	Few	10	1%	5	2%	0	4%	20	≥8%	40
	Alcohol Involved	None	10	Few	5	Mod	0	Mod-High	20	High	40
	Illegal Crossings	None	5	Few	3	Mod	0	Mod-High	10	High	20
VEHICLE	Average Vehicle Volume	Low	5	Mod-Low	3	Mod	0	Mod-High	5	High	20
	Average Vehicle Speed (mph) (kph)	<15 (<25)	5	15-24 (25-39)	3	25-30 (40-49)	0	31-40 (50-65)	10	>40 (>65)	20
	Turning Conflicts	None	5	Few	3	Mod	0	Freq.	5	Many	10
	One-way Traffic		–	Yes	3		–	No	5		–
ENVIRONMENT	Sight Distance	Good	4	Fairly Good	2	Fair	0	Poor	5	Bad	10
	Crossings After Dark (Good Light)	Few	4	Mod-	2	Mod	0		–		
	Crossings After Dark (Poor Light)		–		–	Few	0	Mod	10	Many	20
	Weather	Mild	4	Mod-Mild	2	Mod	0	Mod-Severe	3	Severe	5
CONTROL	Signalization (Presence)			Ped & Veh	10	Veh Only	0	None	20		
	Police Enforcement (Ped Laws)			Heavy	3	Mod	0	Light	3		
	Active Public Education			Yes	2		–	No	2		

Sum the colums as indicated and divide each sum by 100: Decreases ___/100 = ___ Increases ___/100 = ___

Net Involvement Rate is Increase Rate - Decrease Rate _______ + 1 = _______

Avg = Average
Mod = Moderate
Ped = Pedestrian
Veh = Vehicle

FIGURE A-9

ACCIDENT INVOLVEMENT RATE ADJUSTMENT

CHAPTER THREE

INTERPRETATION, APPRAISAL, APPLICATIONS

Potential Applications of Techniques Developed

The primary objective of this research has been to provide a comprehensive methodology for evaluating the social, environmental, and economic benefits of pedestrian facility proposals. Benefits and disbenefits are quantified by a set of measurement techniques developed for the 36 variables presented in Appendix A. The overall evaluation methodology combines analytic measurements of the 36 variables and explicitly stated subjective values (weights) of decision-makers on the relative importance of each variable.

Because many of the variables are subjective in nature (e.g., comfort, attractiveness, noise), the calculation of benefits is performed using a unitless scale of positive and negative values (+10 to -10) for each variable. Positive values correspond to desirable characteristics, and negative values indicate undesirable characteristics. Zero values indicate either "does not apply" or "indifference" (neither good nor bad).

Unitless scoring allows the comparison of alternatives without the need for assigning dollar values to the many noneconomic impacts of pedestrian facilities (and many other public projects). Guidance is also provided for obtaining benefit values in dollars, if required, to allow comparison of pedestrian facilities with other budget expenditures. The primary basic use of the methodology is for the evaluation and comparison of proposals for pedestrian facilities, according to the objectives of this research. This application is described in detail in the next section, "Instructions to Users." Another use of the scoring system is to evaluate existing pedestrian problem locations on a comparative basis. This could be used to indicate the need for improvements on a priority basis. The scoring system may also be used as a design evaluation tool to encourage alterations that will increase the benefits obtained from pedestrian facilities.

The explicit weighting of the relative importance of each variable requires a formalization of preference values for the community. This determination may be made by the decision-maker alone, or may be the result of extensive public participation. Once developed, the explicit use of such weights provides consistent evaluation criteria. These preference weights may be applicable to other public projects as well.

Possibly the greatest advantage of the suggested methodology is that it allows and encourages the use of many benefit measures usually excluded from conventional economic analysis. By reflecting community needs and values that are not easily quantified, use of the method may provide adequate justification for projects not defendable previously by economic analysis alone. Thus, objective benefit measurements, coupled with the explicit identification of relative importance values, produce a method that may aid in "preserving and fostering an urban environment drawn to human scale, with values, services, and facilities that respond fully to the needs of various groups that make up the urban community" (OECD, 1969).

Instructions to Users

Transportation projects, including pedestrian facilities, should be evaluated as early in the planning and design process as is practical, so that shortcomings can be detected and steps taken to remedy them. The evaluation may then be repeated throughout the planning process as often as new plans are proposed or major changes are made to existing plans. The evaluation procedure may also be used as an aid to the design process by purposely designing facilities that will score high values.

Figure 8 is a flowchart of the steps to be performed for a pedestrian facility evaluation. The diamonds are decision points that allow the user the option of taking shortcuts within the overall procedure if time or available resources are limited.

Figure 8A indicates the emphasis and flow of tasks recommended for use with the PPP.

Describe Alternatives

The first step of the process is to describe all of the alternative facilities that are being considered as potential solutions to an existing pedestrian problem. If the study is concerned with only one or a few problem locations or proposed projects, then several alternatives representing a range of solutions should be considered and fully described for the evaluation. Location of the proposed facility, its proposed configuration, projected use levels, user profiles, operation characteristics, and any modifications to existing laws or regulations should be specified.

If an entire city-, region-, or statewide plan for pedestrian transportation is being prepared, the specific project alternatives may not always be defined in as much detail as for a single location. In this case, the locations of proposed improvements may be more important than the improvements themselves.

Estimate Costs

An integral component of the process for identifying project alternatives is to estimate costs for the different pedestrian facilities that are being considered. Table 7 lists all of the major core categories for implementation and operation of pedestrian-oriented facilities. Make the best estimates possible for the costs associated with each category for the facilities being evaluated. Since the primary purpose of the evaluation in most cases is to compare alternatives, the accuracy of the total cost estimate is not as important as the differences in costs for the various alternatives. This should give encouragement to the planner who is uncertain about the magnitudes of individual cost components. The same

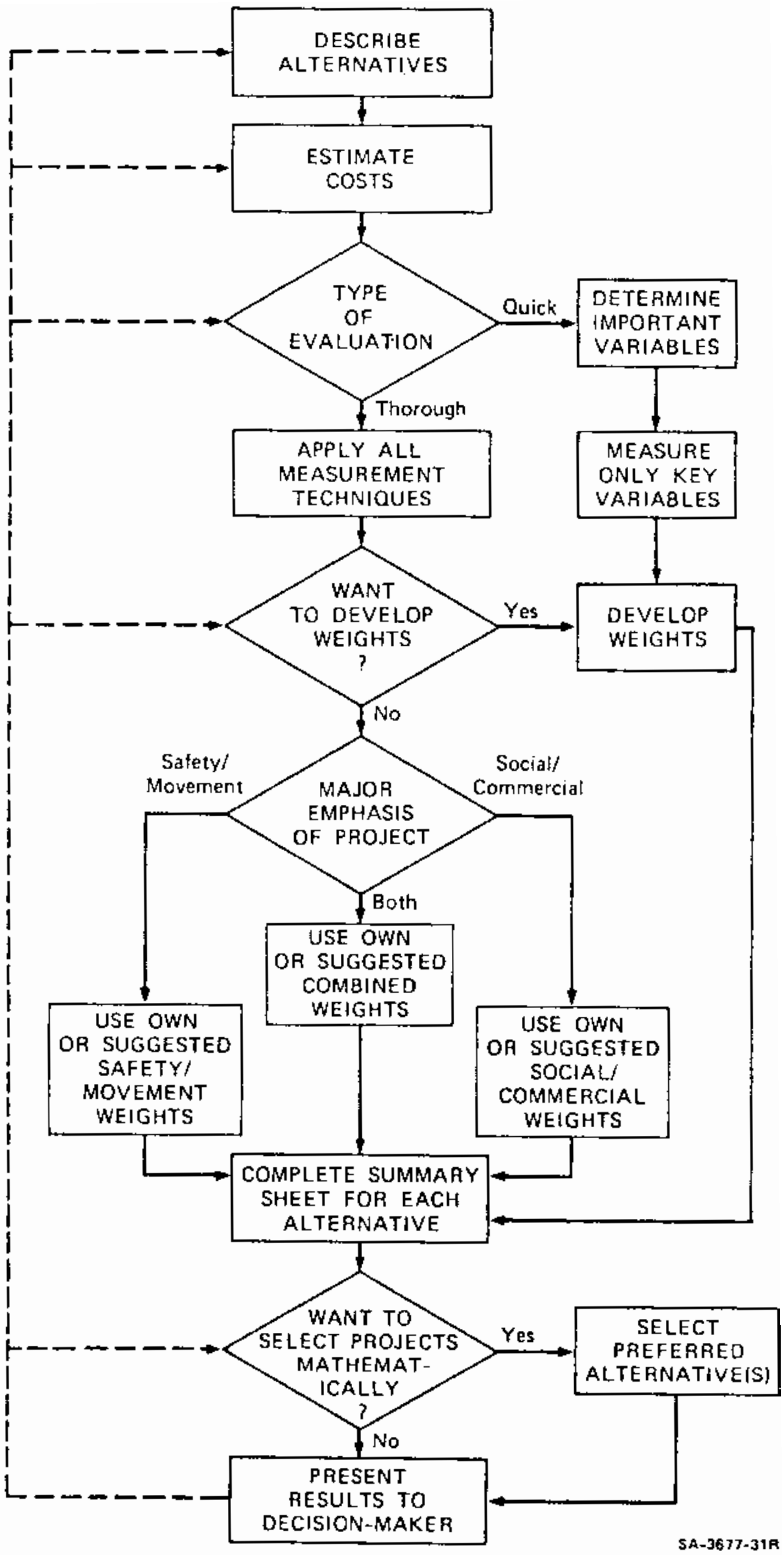


FIGURE 8

PEDESTRIAN FACILITY EVALUATION METHODOLOGY

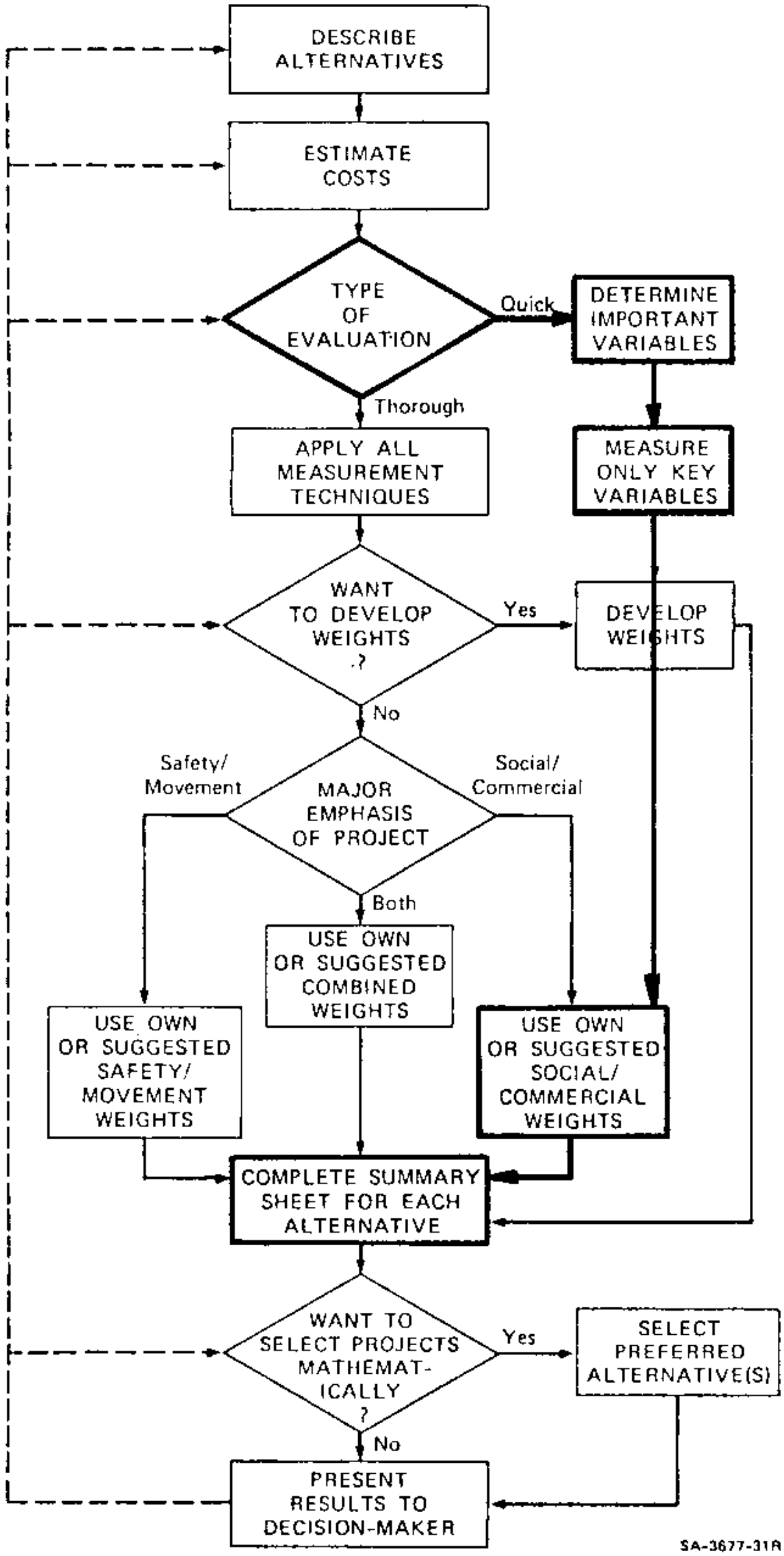


FIGURE 8A

PEDESTRIAN FACILITY EVALUATION METHODOLOGY

TABLE 7

MAJOR COST COMPONENTS OF PEDESTRIAN FACILITIES

1. Design and architect costs

2. Financing costs and legal fees

3. Site preparation

   - Real estate acquisition
   - Demolition
   - Drainage
   - Grading
   - Utilities relocation
   - Foundation

4. Construction

   - Height, width, and length of facility
   - Length of span (if any)
   - Method of support
   - Enclosures (if any)
   - Materials
   - Construction method used

5. Finishing touches

   - Walkway paving, curbs
   - Lighting
   - Street furniture
   - Amenities
   - Landscaping

6. Operation and maintenance

   - Cleaning
   - Gardening
   - Maintenance and repairs
   - Lighting
   - Security
   - Taxes

observation holds for the benefits determination process: differences between alternatives are more important than the actual score for a particular project proposal. However, if a more detail cost estimation procedure is desired at this stage in the evaluation process, the reader is directed to Chapter V, "Facility Costs," of A Manual for Planning Pedestrian Facilities (Prokopy, 1974), which describes a step-by-step costing approach that is tailored for each particular type of facility.

Benefit Assessment

The next step of the methodology is to assess the benefits of the proposed facility. This procedure has been the focal point of the research, and as such will require the greatest effort on the part of the user. However, it is an operation that was previously unavailable, and its existence now will allow more informed public decision-making with complete specification of the impacts of various alternatives.

A total of 36 variables completely specify all primary and secondary impacts of a major facility. However, for quick assessments or for evaluations of very simple facilities, not all of these variables are needed. Therefore, before evaluating any benefits, look through the variables discussed in Appendix A and simply cross out the variables that you do not wish to be included in this particular analysis. (This is equivalent to the assignment of zero benefit to the variables that are eliminated.

Next, apply the instructions for measuring impacts given in Appendix A to all of the variables that remain. Appendix A has been designed to be completely self-contained, so this action is a matter of following the instructions given there, although it may be rather time consuming. Each variable is scored on a uniform +10 to -10 scale. If for any reason it appears that a variable would not apply to a particular facility being evaluated, score zero for that variable.

A project summary sheet (shown in Figure 9) should be prepared for each alternative under consideration. Record the score for each variable in the "variable score" column on the project summary sheet.

Assignment of Weights

After the benefits for each proposed alternative have been quantified by using the measurement techniques in Appendix A and properly recorded on the project summary worksheet, it is time to develop weights that reflect the relative priorities of the different impacts. These may be determined directly by the decision-maker (or his representative) based on inputs from groups affected by the facility; or may be selected from the suggested weights developed during this project on the basis of observations, discussions, the researchers' judgment, and the results of a questionnaire that was distributed to state and local pedestrian facility planners (described in Chapter Two and Appendix C). These suggested priorities assign a positive weight to every variable, so if some of the variables were eliminated from the analysis in the previous step and the sug-

Name of Project ____________

Cost initial $______ annual $______

Total Score [ ]

			Variable Score	Variable Weighting	Weighted Score
1.1 Pedestrian Transportation	1.1.1	Travel Time	____	____	____
	1.1.2	Ease of Walking	____	____	____
	1.1.3	Convenience	____	____	____
	1.1.4	Special Provisions	____	____	____
1.2 Motor Vehicle Transportation	1.2.1	Vehicle Travel Costs	____	____	____
	1.2.2	Use of Automobiles	____	____	____
	1.2.3	Signal/Signing Needs	____	____	____
1.3 Other Community Transportation	1.3.1	Future Transportation Plans	____	____	____
	1.3.2	Existing Transportation	____	____	____
2.1 Safety	2.1.1	Cost of Accidents	____	____	____
	2.1.2	Accident Threat	____	____	____
	2.1.3	Crime Concern	____	____	____
	2.1.4	Emergency	____	____	____
2.2 Attractiveness of Surroundings	2.2.1	Pedestrian Oriented Environment	____	____	____
	2.2.2	Litter Control	____	____	____
	2.2.3	Density	____	____	____
	2.2.4	Climate Control & Weather Protection	____	____	____
2.3 Environment/ Health	2.3.1	Air Pollution	____	____	____
	2.3.2	Noise	____	____	____
	2.3.3	Health	____	____	____
	2.3.4	Conservation	____	____	____
3.1 Residential Neighborhoods	3.1.1	Residential Dislocation	____	____	____
	3.1.2	Community Pride & Inter-action	____	____	____
	3.1.3	Aesthetics & Compatibility	____	____	____
3.2 Commercial/ Industrial Districts	3.2.1	Retail Sales	____	____	____
	3.2.2	Displacement or Renovation	____	____	____
	3.2.3	Deliveries & Commuting	____	____	____
	3.2.4	Attractiveness to Business	____	____	____
4.1 Planning Process	4.1.1	Public Participation	____	____	____
	4.1.2	Requirements & Regulations	____	____	____
4.2 Economic Impacts	4.2.1	Tax Receipts	____	____	____
	4.2.2	Employment	____	____	____
	4.2.3	Community Services	____	____	____
4.3 Community Impacts	4.3.1	Community Activities	____	____	____
	4.3.2	Future Urban Plans	____	____	____
	4.3.3	Construction	____	____	____

FIGURE 9

PROJECT SUMMARY SHEET

gested weights are used without modification, it will not be possible for a facility to achieve a perfect score. This can be remedied by proportionately reallocating to other variables the weights of variables that have been eliminated.

Once a set of weights has been developed or selected by the decision-maker, that set can and should be used for all similar projects. The weights need only be revised occasionally to reflect changes in the preferences of the community, decision-makers, or office-holders. This will produce comparable scores for all proposals evaluated. If the weights are changed significantly, resulting scores cannot be directly compared but must be adjusted by the ratio of the differing weights.

Direct Determination

The purpose of developing a set of weights is to incorporate the decision-maker's perception of the relative importance of changes in degree of impact of the evaluation variables used in the methodology. The procedure is to assign a separate set of values expressed in percentages for each of the three levels of impacts (categories, groups, and variables), the sum of each level being 100%. When the precentage values assigned to the three levels for a particular variable are all multiplied together, the resulting product indicates the relative importance of that factor in the total evaluation process. For example, if the following values are assigned to these headings: Transportation Category = 20%, Pedestrian Group = 40%, Travel Time Variable = 30%, by multiplying (.2 x .4 x .3 = .024 = 2.4%), a value of 2.4% is obtained as the relative weight of the variable "Travel Time" (1.1.1).

The following procedure is suggested to assist the reader in developing a set of relative values:

(1) Refer to Figure 10, which is a work sheet for use in assigning a set of values as described above.

(2) Review Appendix A and the results of the measurements to become become familiar with the categories and descriptions of the variables as listed on the work sheet (Figure 10).

(3) Rank order (1, 2, 3, and so on) each of the three levels of impacts. First rank order the major categories, then the groups within each major category, and finally each subset of individual variables. This may be easier than attempting to assign actual values on the first attempt.

(4) Repeat Step 3 refining the rank ordering into percentages. This is illustrated in Figure 11, a complete sample work sheet. Zero is a legitimate percentage value to use at any level (e.g., Signal/Signing Needs Adjacent to Facility in Figure 11). Zeroes should also be assigned to the variables that were previously eliminated from the evaluation.

Types of Facilities Being Evaluated

- [ ] Safety/Movement Only
- [ ] Social/Commercial Only
- [ ] Both Types Together

Rank Order	Percent-Ages	Levels of Impacts	Weight of Each Variable
___/___%	I.	Transportation	
	___/___%	Pedestrians	
		___/___% Travel Time	____%
		___/___% Ease of Walking	____
		___/___% Convenience (Access and Availability)	____
		___/___% Special Provision for Various Groups	____
		(100%)	
	___/___%	Motor Vehicles	
		___/___% Motor Vehicle Travel Costs	____
		___/___% Use of Automobiles	____
		___/___% Signal/Signing Needs Adjacent to Facility	____
		(100%)	
	___/___%	Other Community Transportation	
		___/___% Adaptability to Future Transportation Development Plans	____
		___/___% Impact on Use of Other Transportation Systems	____
	(100%)	(100%)	
___/___%	II.	Safety/Environment/Health	
	___/___%	Safety	
		___/___% Societal Cost of Accidents	____
		___/___% Accident Threat Concern	____
		___/___% Crime	____
		___/___% Emergency Access/Medical and Fire Facilities	____
		(100%)	
	___/___%	Attractiveness of Surroundings	
		___/___% Pedestrian Oriented Environment	____
		___/___% Litter Control	____
		___/___% Density	____
		___/___% Climate Control and Weather Protection	____
		(100%)	
	___/___%	Environment/Health	
		___/___% Effects of Air Pollution	____
		___/___% Noise Impacts of Motor Vehicles	____
		___/___% Health Effects of Walking (exercise, fatigue, etc.)	____
		___/___% Conservation of Resources	____
	(100%)	(100%)	
___/___%	III.	Residential/Business	
	___/___%	Residential Neighborhoods	
		___/___% Residential Dislocation	____
		___/___% Community Pride, Cohesiveness, and Social Interaction	____
		___/___% Aesthetic Impact, Compatibility with Neighborhood	____
		(100%)	
	___/___%	Commercial/Industrial Districts	
		___/___% Gross Retail Sales	____
		___/___% Displacement or Renovation	____
		___/___% Ease of Deliveries and Employee Commuting	____
		___/___% Attractiveness of Area to Business	____
3	(100%)	(100%)	
___/___%	IV.	Government/Institutional	
	___/___%	Transportation and Land Use Planning Process	
		___/___% Public Participation in the Planning Process	____
		___/___% Conformance with Requirements and Regulations	____
		(100%)	
	___/___%	Economic Impacts	
		___/___% Net Change in Tax Receipts and Other Revenue	____
		___/___% Resulting Changes in Employment	____
		___/___% Change in Cost of Providing Community Services	____
		(100%)	
	___/___%	Community Impacts	
		___/___% Community Activities	____
		___/___% Adaptability to Future Urban Development Plans	____
		___/___% Construction Period	____
(100%)	(100%)	(100%)	(100%)

FIGURE 10

WORKSHEET

Types of Facilities Being Evaluated

- ☐ Safety/Movement Only
- ☐ Social/Commercial Only
- ☐ Both Types Together

Rank Order	Percentages			Levels of Impacts	Weight of Each Variable
2/20%	I.			Transportation	
		1/40%		Pedestrians	
			1/30%	Travel Time	2.4%
			4/20%	Ease of Walking	1.6
			3/20%	Convenience (Access and Availability)	1.6
			2/30%	Special Provision for Various Groups	2.4
			(100%)		
		2/40%		Motor Vehicles	
			1/90%	Motor Vehicle Travel Costs	7.2
			2/10%	Use of Automobiles	.8
			3/0%	Signal/Signing Needs Adjacent to Facility	0
			(100%)		
		3/20%		Other Community Transportation	
			1/80%	Adaptability to Future Transportation Development Plans	3.2
			2/20%	Impact on Use of Other Transportation Systems	.8
		(100%)	(100%)		
1/60%	II.			Safety/Environment/Health	
		1/80%		Safety	
			1/70%	Societal Cost of Accidents	33.6
			2/10%	Accident Threat Concern	4.8
			3/10%	Crime	4.8
			4/10%	Emergency Access/Medical and Fire Facilities	4.8
			(100%)		
		3/10%		Attractiveness of Surroundings	
			2/30%	Pedestrian Oriented Environment	1.8
			4/10%	Litter Control	.6
			1/40%	Density	2.4
			3/20%	Climate Control and Weather Protection	1.2
			(100%)		
		2/10%		Environment/Health	
			1/40%	Effects of Air Pollution	2.4
			3/30%	Noise Impacts of Motor Vehicles	1.8
			2/20%	Health Effects of Walking (exercise, fatigue, etc.)	1.2
			4/10%	Conservation of Resources	.6
		(100%)	(100%)		
3/10%	III.			Residential/Business	
		1/50%		Residential Neighborhoods	
			2/20%	Residential Dislocation	1.0
			3/30%	Community Pride, Cohesiveness, and Social Interaction	1.5
			1/50%	Aesthetic Impact, Compatibility with Neighborhood	2.5
			(100%)		
		2/50%		Commercial/Industrial Districts	
			1/50%	Gross Retail Sales	2.5
			2/20%	Displacement or Renovation	1.0
			4/10%	Ease of Deliveries and Employee Commuting	.5
			3/20%	Attractiveness of Area to Business	1.0
	3	(100%)	(100%)		
4/10%	IV.			Government/Institutional	
		2/20%		Transportation and Land Use Planning Process	
			1/60%	Public Participation in the Planning Process	1.2
			2/40%	Conformance with Requirements and Regulations	.8
			(100%)		
		3/10%		Economic Impacts	
			1/50%	Net Change in Tax Receipts and Other Revenue	.5
			3/20%	Resulting Changes in Employment	.2
			2/30%	Change in Cost of Providing Community Services	.3
			(100%)		
		1/70%		Community Impacts	
			1/60%	Community Activities	4.2
			3/20%	Adaptability to Future Urban Development Plans	1.4
			2/20%	Construction Period	1.4
(100%)		(100%)	(100%)		(100%)

FIGURE 11

COMPLETED WORKSHEET

(5) Review the assigned weights and revise them if desired. Check the arithmetic to see that each sum adds to 100%.

(6) Multiply the three level weights together to determine and compare the resulting relative weight of each individual factor. Round the percentages to the nearest tenth, e.g., 25% x 35% x 30% = 0.02625 is rounded to 2.6%.

(7) If desired, it is possible to allow different constituencies to express their individual preferences. Have a representative of each group indicate its preferences on a copy of Figure 10. These multiple results may then be used in one of three ways:

- If equal importance is applied to each of the groups completing the worksheet, then simply take the average weight for each variable from the last column of the worksheets prepared by the groups as the composite weight.

- If some groups are more important, vocal, or influential than others, assign weights (adding up to 100%) indicating the relative importance of the groups. Then take the weighted average for each variable from the last column of the completed worksheets as the composite weight.

- If the different groups have completely different sets of values, a composite weighting would not reflect the variance. For example, if values assigned to safety were 40% and 2%, the average, 21%, is a compromise that does not indiçate how highly safety is valued by the first group nor how small it is valued by the other. In these cases, it is not necessary to combine the community's preferences at this point. Perform a separate evaluation of the alternatives for each group. Each evaluation would use the same objective measurements, but the weights will be different. Present the objective measurements, each group's subjective weights, and final score for the proposed project alternatives to the community and to the decision-maker or to the community and allow the decision-maker to achieve a compromise based on public meetings, private meetings, and his own judgment.

(8) Transfer the results from the last column of weight assignment worksheet (Figure 10) to the second column of the Project Summary Sheet (Figure 9).

Use of Suggested Weights. If a quick evaluation is being performed, it is possible to apply a set of weights developed by the researchers, rather than the reader. One advantage of these standard weights (other than the obvious time and effort savings) is that evaluations performed in different cities or states will be directly comparable. Even if the reader is developing weights to represent community preference, an examination of the suggested weights might provide insights, particularly on the difference in emphasis between facility types.

We have identified two types of pedestrian facilities based on their major purpose. The safety/movement type includes those facilities where severe pedestrian/vehicle conflicts occur or where high pedestrian volumes result in congestion, and the primary intent is to provide safe unimpeded pedestrian movement. The social/commercial type includes planned activity pedestrianization where the major purpose is to provide a safe and enjoyable place for pedestrians to move leisurely and stop. Overpasses are examples of the first type, and malls are examples of the second type.

Suggested weights for safety or movement facilities are depicted in Figure 12. Figure 13 gives the recommended weights for social or commercial facilities. If the evaluation combines both project types, use the weights given in Figure 12. Transfer the weights from the final column of the appropriate figure to the second column of the Project Summary Worksheet (Figure 9).

(NOTE: See Insert Fig. 13A for Manual's recommended weights as applied to selected variables.)

Summary Step

At this point in the evaluation, the project summary sheet should have the first two columns ("Variable Score" and "Variable Weighting") completed. The sheet should also indicate the name of the project and the initial construction and annual operating costs for each alternative considered. The third column (weighted score) is completed by multiplying the objective measurement score for each variable (first column) by the weight (second column) in percent (not decimal form). The total weighted score of the benefits for a pedestrian facility is simply the sum of all the individual weighted scores. The use of percent values as indicated above will result in a "Total Score" for the facility between -1000 and +1000, which is more suitable for comparing projects than the -10 to +10 scale appropriate for measuring individual benefit variables.

This completes the project evaluation. A complete project summary sheet for each proposed alternative summarizes all of the important information about the impacts of the project. Priorities for a small set of alternatives or a single go/no-go decision may be made directly. If a large number of alternatives are being investigated or a budget allocation programming is being performed, then the reader may wish to follow the discussion of "Decision Rules for Project Selection" in Chapter Two.

Figure 14 is a sample Project Summary Sheet for the Sparks Street Mall. Summary sheets for the other three case studies are included in Appendix B.

Name of Project ________________

Cost initial$______ annual $______

Total Score [ ]

Category	No.	Variable	Variable Score	Variable Weighting	Weighted Score
1.1 Pedestrian Transportation	1.1.1	Travel Time		2.5 %	
	1.1.2	Ease of Walking		3.0	
	1.1.3	Convenience		3.5	
	1.1.4	Special Provisions		2.5	
1.2 Motor Vehicle Transportation	1.2.1	Vehicle Travel Costs		6.0	
	1.2.2	Use of Automobiles		2.5	
	1.2.3	Signal/Signing Needs		2.0	
1.3 Other Community Transportation	1.3.1	Future Transportation Plans		3.0	
	1.3.2	Existing Transportation		3.0	
2.1 Safety	2.1.1	Cost of Accidents		12.0	
	2.1.2	Accident Threat		7.0	
	2.1.3	Crime Concern		3.0	
	2.1.4	Emergency		3.5	
2.2 Attractiveness of Surroundings	2.2.1	Pedestrian Oriented Environment		5.0	
	2.2.2	Litter Control		1.0	
	2.2.3	Density		1.5	
	2.2.4	Climate Control & Weather Protection		1.5	
2.3 Environment/ Health	2.3.1	Air Pollution		3.0	
	2.3.2	Noise		1.5	
	2.3.3	Health		1.5	
	2.3.4	Conservation		1.5	
3.1 Residential Neighborhoods	3.1.1	Residential Dislocation		2.0	
	3.1.2	Community Pride & Inter-action		3.5	
	3.1.3	Aesthetics & Compatibility		3.0	
3.2 Commercial/ Industrial Districts	3.2.1	Retail Sales		1.5	
	3.2.2	Displacement or Renovation		1.5	
	3.2.3	Deliveries & Commuting		2.0	
	3.2.4	Attractiveness to Business		2.5	
4.1 Planning Process	4.1.1	Public Participation		2.5	
	4.1.2	Requirements & Regulations		2.0	
4.2 Economic Impacts	4.2.1	Tax Receipts		1.5	
	4.2.2	Employment		1.0	
	4.2.3	Community Services		1.5	
4.3 Community Impacts	4.3.1	Community Activities		2.5	
	4.3.2	Future Urban Plans		2.0	
	4.3.3	Construction		1.0	

FIGURE 12

SUGGESTED SAFETY/MOVEMENT OR COMBINED WEIGHTS

Name of Project ____________

Cost initial $______ annual $______

Total Score [ ]

Category	Variable		Variable Score	Variable Weighting	Weighted Score
1.1 Pedestrian Transportation	1.1.1	Travel Time	____	1.5 %	____
	1.1.2	Ease of Walking	____	2.5	____
	1.1.3	Convenience	____	3.5	____
	1.1.4	Special Provisions	____	3.0	____
1.2 Motor Vehicle Transportation	1.2.1	Vehicle Travel Costs	____	0.5	____
	1.2.2	Use of Automobiles	____	1.0	____
	1.2.3	Signal/Signing Needs	____	1.5	____
1.3 Other Community Transportation	1.3.1	Future Transportation Plans	____	1.5	____
	1.3.2	Existing Transportation	____	3.0	____
2.1 Safety	2.1.1	Cost of Accidents	____	3.0	____
	2.1.2	Accident Threat	____	2.0	____
	2.1.3	Crime Concern	____	3.0	____
	2.1.4	Emergency	____	3.0	____
2.2 Attractiveness of Surroundings	2.2.1	Pedestrian Oriented Environment	____	10.0	____
	2.2.2	Litter Control	____	2.0	____
	2.2.3	Density	____	2.0	____
	2.2.4	Climate Control & Weather Protection	____	2.0	____
2.3 Environment/Health	2.3.1	Air Pollution	____	4.0	____
	2.3.2	Noise	____	2.5	____
	2.3.3	Health	____	2.5	____
	2.3.4	Conservation	____	2.0	____
3.1 Residential Neighborhoods	3.1.1	Residential Dislocation	____	2.0	____
	3.1.2	Community Pride & Interaction	____	6.0	____
	3.1.3	Aesthetics & Compatibility	____	4.0	____
3.2 Commercial/Industrial Districts	3.2.1	Retail Sales	____	2.5	____
	3.2.2	Displacement or Renovation	____	2.5	____
	3.2.3	Deliveries & Commuting	____	2.5	____
	3.2.4	Attractiveness to Business	____	4.5	____
4.1 Planning Process	4.1.1	Public Participation	____	3.5	____
	4.1.2	Requirements & Regulations	____	1.0	____
4.2 Economic Impacts	4.2.1	Tax Receipts	____	3.5	____
	4.2.2	Employment	____	2.0	____
	4.2.3	Community Services	____	1.0	____
4.3 Community Impacts	4.3.1	Community Activities	____	5.0	____
	4.3.2	Future Urban Plans	____	2.5	____
	4.3.3	Construction	____	1.5	____

FIGURE 13

SUGGESTED SOCIAL/COMMERCIAL WEIGHTS

Name of Project ________________ Cost initial $______ annual $______

			Variable Score	Variable Weighting	Total Score Weighted Score
1.1 Pedestrian/ Transportation	1.1.1	Travel Time	______	5%	______
	1.1.2	Ease of Walking	______	5%	______
	1.1.3	Convenience (Access and Availability)	______	10%	______
1.3 Other Community Transportation	1.3.1	Adaptability to Future Transportation Development Plans	______	3.3%	______
	1.3.2	Impact on Use of Existing Transportation Systems	______	6.7%	______
2.1 Safety	2.1.1	Societal Cost of Accidents	______	1.2%	______
	2.1.2	Accident Threat Concern	______	4.4%	______
	2.1.3	Crime Concern	______	4.4%	______
2.2 Attractiveness of Surroundings	2.2.1	Pedestrian Oriented Environment	______	5.5%	______
	2.2.4	Climate Control and Environment	______	3.3%	______
2.3 Environment/ Health	2.3.4	Conservation of Resources	______	1.2%	______
3.1 Residential Neighborhoods	3.1.2	Community Pride, Cohesiveness, and Social Interaction	______	5%	______
	3.1.3	Aesthetic Impact, and Compatibility with Neighborhood	______	5%	______
3.2 Commercial/ Industrial Districts	3.2.1	Gross Retail Sales	______	10%	______
	3.2.3	Ease of Deliveries and Employee Commuting	______	1.7%	______
	3.2.4	Attractiveness of Area to Business	______	8.3%	______
4.1 Planning Process	4.1.1	Public Participation in the Planning Process	______	4%	______
4.2 Economic Impacts	4.2.1	Net Change in Tax Receipts and Other Revenue	______	8%	______
4.3 Community Impacts	4.3.1	Community Activities	______	2%	______
	4.3.2	Adaptability to Future Urban Development Plans	______	6%	______

FIGURE 13A

SUGGESTED SOCIAL/COMMERCIAL WEIGHTS
(As Revised For PPP)

Name of Project SPARKS STREET MALL

Cost initial $ 1500000 annual $ 34,800

+391 Total Score

			Variable Score	Variable Weighting	Weighted Score
1.1 Pedestrian Transportation	1.1.1	Travel Time	+1	1.5 %	2
	1.1.2	Ease of Walking	+7	2.5	18
	1.1.3	Convenience	+4	3.5	14
	1.1.4	Special Provisions	0	3.0	0
1.2 Motor Vehicle Transportation	1.2.1	Vehicle Travel Costs	+1	0.5	1
	1.2.2	Use of Automobiles	+1	1.0	1
	1.2.3	Signal/Signing Needs	0	1.5	0
1.3 Other Community Transportation	1.3.1	Future Transportation Plans	+5	1.5	8
	1.3.2	Existing Transportation	0	3.0	0
2.1 Safety	2.1.1	Cost of Accidents	+6	3.0	18
	2.1.2	Accident Threat	+8	2.0	16
	2.1.3	Crime Concern	+8	3.0	24
	2.1.4	Emergency	+6	3.0	18
2.2 Attractiveness of Surroundings	2.2.1	Pedestrian Oriented Environment	+7	10.0	70
	2.2.2	Litter Control	0	2.0	0
	2.2.3	Density	-4	2.0	-8
	2.2.4	Climate Control & Weather Protection	-6	2.0	-12
2. 3 Environment/ Health	2.3.1	Air Pollution	+5	4.0	20
	2.3.2	Noise	+4	2.5	10
	2.3.3	Health	+4	2.5	10
	2.3.4	Conservation	+10	2.0	20
3.1 Residential Neighborhoods	3.1.1	Residential Dislocation	0	2.0	0
	3.1.2	Community Pride & Interaction	+4	6.0	24
	3.1.3	Aesthetics & Compatibility	0	4.0	0
3.2 Commercial/ Industrial Districts	3.2.1	Retail Sales	+4	2.5	10
	3.2.2	Displacement or Renovation	+1	2.5	3
	3.2.3	Deliveries & Commuting	-5	2.5	-13
	3.2.4	Attractiveness to Business	+6	4.5	27
4.1 Planning Process	4.1.1	Public Participation	+6	3.5	21
	4.1.2	Requirements & Regulations	+10	1.0	10
4.2 Economic Impacts	4.2.1	Tax Receipts	0	3.5	0
	4.2.2	Employment	+2	2.0	4
	4.2.3	Community Services	0	1.0	0
4.3 Community Impacts	4.3.1	Community Activities	+10	5.0	50
	4.3.2	Future Urban Plans	+10	2.5	25
	4.3.3	Construction	0	1.5	0

FIGURE 14

SAMPLE PROJECT SUMMARY SHEET FOR THE SPARKS STREET MALL

Conversion to Dollar Values (Optional)

If it becomes desirable to estimate a dollar value for all benefits (for example, to compare with other types of public projects), the following procedure can be used. Record the computed dollar values from Appendix A before conversion to unitless scoring for Motor Vehicle Travel Costs (1.2.1), Gross Retail Sales (3.2.1), Renovation Costs (3.2.2), Tax Receipts and Other Revenue (4.2.1), and Cost of Providing Community Services (4.3.2). Then use the sections "Value of Pedestrian Travel Time" and "Societal Cost of Accidents" in Chapter Two to compute dollar value estimates for those two variables (1.1.1 and 2.1.1, respectively).

The remaining 29 variables are not readily quantified in dollars, but proxy dollar values can be established by deriving a value per point from the costable variables. For example, if Motor Vehicle Travel Costs (1.2.1) scored +10 points, and was weighted at 15%, the weighted score would be 150 points (10 points x 15%). If the dollar value was $15,000, each weighted scoring point would be estimated at $100. This procedure should be followed for all seven of the costable variables and an average point value should be computed to apply to the noncostable variables. For example, if the average point value was $100, then if Accident Threat Concern (2.1.2) scored +5 points and was weighted at 6%, its weighted score would be 30 points (5 points x 6%), and its proxy dollar value would be $3,000 ($100 x 30 weighted points). A total project dollar benefit value can then be obtained for this example by adding the products of the average point value times the weighted scoring point for each noncostable variable to the dollar values of the seven costable variables identified in the previous paragraph.

An alternative approach is to calculate the average point value of similar types of pedestrian facilities, either approved for construction or already constructed, using their total cost as a rough measure of their benefits. (Such costs should be escalated to current price levels in the case of completed facilities.) A point value obtained this way would provide a lower bound on what the community has demonstrated it is willing to pay per point for such facilities. High values per benefit point can be used if benefits are judged by the community to have exceeded costs for completed projects.

APPENDIX A (within SUPPLEMENT 16)

MEASUREMENT TECHNIQUES FOR EVALUATING PEDESTRIAN FACILITY VARIABLES

1. Transportation

Economic costs have traditionally dominated the planning, evaluation, and selection of transportation projects, not because the intangibles were viewed as unimportant, but rather because the means for measuring them were not generally accepted. Today, there is still no generally accepted procedure for assessing traveler and travel-related impacts of transportation projects, but there is a definite trend and an established need for the inclusion of these factors in the analysis. Our suggested solution to fill this need is provided with the nine variables described in the following pages. Only one of these variables (1.2.1, Motor Vehicle Travel Costs) is an economic cost; the eight remaining factors are more intangible, such as pedestrian comfort and convenience.

1.1 Pedestrians

None of the four variables, travel time, ease of walking, convenience, and special provisions, to be described for the evaluation of pedestrian transportation, are costable in dollars although they can all be evaluated objectively. Pedestrian travel time (1.1.1) can be expressed in dollars, as is done for motor vehicle travel time, but the objective is to evaluate all variables on a unitless +10 to -10 scale. For the convenience of those who are performing other types of analyses, for which a dollar assignment to pedestrian travel time might be useful, a discussion of unit pedestrian travel time values has been included in Section 2.

1.1.1 Travel Time.

This variable is concerned with the computation of total pedestrian travel time for a particular facility. It may be computed according to formula (1) below:

$$\text{Total travel time} = \text{number of pedestrians} \times \left(\frac{\text{route length}}{\text{walking speed}} + \text{signal delay} \right) \quad (1)$$

The following sections describe procedures for evaluating the components of equation (1).

1.1.1.1 Number of Pedestrians and Route Length.

Both of these variables are inherent to the planning and design process for pedestrian facilities, which is described as step 4 of the suggested evaluation process (Figure 2) described in Chapter Two.

Route length may be determined from plans for the facility such as engineering drawings or blueprints as part of step 4. In general, pedestrian routes will be less than 3,000 feet (915 meters) in length. To avoid circuitous routing, walking distance should be equal to no more than approximately 1.4 times the straight line distance from origin to destination, and preferably less than 1.2 times (Vuchic and Kikuchi, 1974). If pedestrians have alternate routes to choose from, determine average route length based on the proportion of pedestrians who do (or are expected to) use the various routes.

1.1.1.2 Walking Speed.

Average unimpeded pedestrian speed is about 295 feet per minute (1.50 meters per second).* This is the value stated by Oeding (1963), the upper end of the range given by Lovemark (1972), and is in excellent agreement with Hoel (1968) and Claxton (1974). This is an average value for general applications, when there are no impedances to flow. For commuters in busy downtown areas, 267 feet per minute (Fruin, 1971) is a better value; whereas 320 feet per minute (Navin and Wheeler, 1969, agrees with Hankin and Wright, 1958) is more appropriate for students. The researchers measured pedestrian travel speeds of 270 to 300 feet per minute in downtown Ottawa, and 244 to 258 feet per minute in downtown Brooklyn (slower because of high pedestrian density).

When there is a concentration of pedestrians in an area, naturally, these speeds will be reduced. The speed is reduced by an amount directly proportional to the density of the pedestrians according to formula (2) below, but this correction only becomes significant at high densities such as one pedestrian per ten square feet:

$$\text{Adjusted speed} = \text{speed} - B \times \text{pedestrian density} \qquad (2)$$

Values for B, which when divided by the initial speed equals the theoretical maximum space allocation per pedestrian at the point when congestion causes everyone to halt, are as follows (Pushkarev and Zupan, 1975a):

Type of Flow	Initial Speed (feet/minute)	B (feet^3/minute)
Downtown commuters	267	722
Mixed traffic	295	835
Students	320	1,280

*To convert the other travel speeds in this discussion from feet per minute to meters per second, multiply by 0.00508.

For example, if a downtown mall had a total area of 500,000 square feet and 1,000 commuters were walking through it, then

$$\text{Adjusted speed} = \text{speed} - B \times \text{density}$$

$$\text{Adjusted speed} = 295\ \frac{\text{feet}}{\text{minute}} - 835\ \frac{\text{feet}^3}{\text{minute}} \times \frac{1{,}000}{500{,}000\ \text{feet}^2}$$

$$\text{Adjusted speed} = 293\ \frac{\text{feet}}{\text{minute}}$$

only a minor correction.

In addition to density, walking speed reduction of up to 25% may occur for extreme age or grades. However, no corrections are necessary for ages less than 65 years nor for grades of up to 5% (Fruin, 1971). Also, pedestrians walk about 10% faster in subfreezing weather than they do in 65° to 75°F (18°C to 24°C) temperatures, according to Lester Hoel (1968), so when examining wintertime use of facilities in cold-weather climates, increase the assumed walking speed by 10%.

1.1.1.4 Signal Delay.

Pedestrian delay at signalized intersections can be determined from a simple calculation based on signal timing measurements. It is assumed from experience that pedestrians arrive at random times and that they will begin to cross at any time during the green phase. If fraction F of the pedestrians wait when they arrive at a red, amber, or flashing "DON'T WALK" signal, then the mean delay is given by formula (3):

$$D = \frac{F(R + A)^2}{2(G + R + A} \qquad (3)$$

where

D = average delay per pedestrian

F = the fraction of pedestrians who obey the signal

R = the duration of the red or "DON'T WALK" signal

A = the duration of the amber or flashing "DON'T WALK" signal

G = the duration of the green or "WALK" signal.

Of course, for a pedestrian-actuated signal, parameters for pedestrian delay must be established based on the particular characteristics of the traffic control device.

Calculation of the delay most likely to be incurred by pedestrians at crossings without signals or signs has been made by Joyce et al. (1975), based on empirical measurements made in the London Borough of Hammersmith and the Royal Boroughs of Kensington and Chelsea, both in the United Kingdom. The formula (4), which assumes that the pedestrian will cross the street directly in one movement rather than cross halfway and wait, is as follows:

$$D = 6.7 \times 10^{-6}(Q)^2 + 0.3 \qquad (4)$$

where D = delay most likely to be incurred, in seconds, and Q = total hourly vehicle flow in both directions. The formula is not valid for vehicle flows of greater than 1600 per hour or for mean delays greater than 18 seconds, when more site-specific relationships must be developed based on vehicle mix and speeds, street width, and pedestrian population.

1.1.1.5 Total Travel Time.

Once the route length and walking speed for the types of pedestrians expected to use the pedestrian facility have been determined, distance should be divided by speed to obtain the travel time for each trip across the facility. This time per trip should then be multiplied by the number of pedestrians expected to use the facility to obtain total time. Symbolically, for each grouping of pedestrians:

Time per trip = route length walking speed (5)

Total time = no. of pedestrian trips x time per trip (6)

1.1.1.6 Unit Pedestrian Travel Time Savings.

This information may be recorded on the following chart. Weighting the travel times for the four groups shown is recommended, based on each group's mean wage rate. The value of time for people who are walking in the course of their work should be valued at 1.5 times the value for commuters and workers on lunch break because of the money expended by their employers for salary, payroll taxes, and overhead or profit. Similarly, other pedestrians, particularly those on leisure trips, personal business, or persons who are not employed have a time value about half of that for commuters, because pedestrian travel time savings cannot be readily converted into employment for them. The value of time for elementary school children is very low (one-tenth of that for commuters, unless their travel decision is made by a parent, in which case it might be higher) because they have very little money but lots of free time.

	BEFORE	AFTER
Number of commuters or workers on lunch break	______	______
Travel time per person	______	______
Total travel time	______	______
Number of people walking in the course of their work	______	______
Travel time per person	______	______
Total travel time	______	______
Multiply by 1.5	______	______
Number of elementary school children	______	______
Travel time per child	______	______
Total travel time	______	______
Multiply by 0.1	______	______
Number of other pedestrians	______	______
Travel time per person	______	______
Total travel time	______	______
Multiply by 0.5	______	______
Total travel time in equivalent minutes	______	______

Weighting commuter's time by 1, the travel time of people walking in the course of their work by 1.5, elementary school children's time by 0.1, and other pedestrian time by 0.5 will result in a total travel time in "equivalent" minutes, equivalent to the specified amount of travel time for commuters or those workers on their lunch break.

A unitless score for travel time is obtained by using formula (7) below, and the values of Total Travel Time in equivalent minutes determined using the chart above:

$$\text{Total TRAVEL TIME SCORE} = \frac{\text{total travel time before} - \text{total travel time after}}{\text{maximum of above terms}} \times 10$$

$$= \_\_\_\_\_\_\_\_ \qquad (7)$$

If this evaluation is being used to compare a number of sites, the maximum value indicated above should be the largest term for all sites under consideration.

1.1.2 Ease of Walking.

Ease of walking may be described in terms of five components: condition of the walking surface, grade changes, path continuity, signing, and lighting. Techniques for measuring these components are described in the following sections. The range in number of points assigned to each is shown in the tabulation below, which may also be used to summarize the scores of the different sections.

	Scoring Range	Score
Walking surface	-2 to 2	
Grade changes	-4 to 2	
Continuity	-1 to 2	
Signing	-1 to 2	
Lighting	-2 to 2	____
Total EASE OF WALKING SCORE	-10 to 10	

1.1.2.1 Walking Surface.

Check off the appropriate boxes in response to the questions below.

	YES	SOMEWHAT	NO
Is the walking surface aesthetically appealing? Consider color, texture, and sound.	1/2	0	-1/2
Is the surface comfortable to walk on, even for someone who is wearing high-heel shoes or sandals? A comfortable walking surface is neither too hard nor too soft. Considering comfort only, dry soil is ideal. Concrete is too hard, whereas sand is too soft.	1/2	0	-1/2

Is the pavement free of severe cracks or holes?	1/2	0	-1/2
Is the surface slip-proof, especially when wet or freezing?	1/2	0	-1/2

WALKING SURFACE SCORE is the sum of values in boxes checked = ______.

1.1.2.4 Signing.

Check off the appropriate boxes in response to the questions below.

	YES	NO	UNNECESSARY
Are directions to important destinations given or mpas of the area provided?	1	0	1
Is there proper signing for safety?	1	0	1
Are any rules or other important information conveyed if necessary?	1	0	1
Are the signs simple and easy to understand?	1	0	1
Can they be understood by persons who cannot read English?	1	0	1
Can they be read by persons with poor eyesight or colorblindness?	1	0	1
Are signs located at likely points of confusion or indecision?	1	0	1
Is there a clear, unobstructed view of each sign?	1	0	1
Are the signs illuminated properly, free of glare?	1	0	1

Signing Point Score is sum of value in boxes checked = ______

Total SIGNING SCORE is Point Score _____ 3 ______ - 1 = ______

1.1.2.5 Lighting.

Lighting effectiveness can be measured in terms of the amount of illumination, the type of lighting, and the height of the lamps.

Level of Illumination. Now that energy conservation is generally accepted as a desirable public policy, lighting standards may be lowered accordingly, if they continue to satisfy safety and comfort criteria. Thus, existing standards or rules of thumb should not be accepted without question, and reevaluation may be warranted.

The illumination level may be measured with a small hand-held light meter. The investigators used one manufactured by General Electric, Lamp Division, Application Engineering Department, located in Cleveland, Ohio; but there are equivalent meters available. Also, when making test measurements, it was found that the ambient light in a city (until around midnight in the case of Ottawa) can add 5 foot-candles* or more to each reading, so it is best to perform these measurements very late at night (for outdoor facilities), after most of the city has gone to sleep. The measurements should be made about five feet (1.5 meters) above the ground at representative pedestrian locations. Try to measure an average location, taking into consideration the placement of lights, rather than use an average of the measurements taken. The level of illumination can be translated into a point value according to the following table.

Level of Illumination (foot candles)*	Points
15 or more	0
10 or more	-0.5
5 or more	-1.5
2 or more	-2.0
less than 2	-2.5

Level Score selected = ________

Type of Lighting. Certain types of lighting (such as incandescent) are soft to the eye, whereas others (such as sodium or strontium vapor) ar very harsh. Fluorescent and neon lights fall somewhere in between. Scores are assigned to these differing degrees of harshness or softness as follows:

*To convert foot candles to lumen per square meter (lux) multiply by 10.764.

Type of Lighting	Points
Soft: incandescent	0
Medium: neon or fluorescent	-0.5
Harsh: sodium or strontium vapor	-1

Type Score selected = ________

Height of Lamps. Highways are wide and must accommodate tall vehicles, so the lights are located on poles 40 feet (12 meters) high. This height is unnecessary and undesirable for pedestrian activity areas, for which 10 or 12 foot (3 meter) pole heights are more suitable. Check the box below that applies.

Height of Lamps	Points
Lighting is on a pedestrian scale	0
Lighting is automobile oriented	-0.5

Height Score selected = ________

Combined Lighting Score. COMBINED LIGHTING SCORE is Level Score + Type Score + Height Score = ________, + 2 = ________.

1.1.3 Convenience (Availability and Access).

This variable is measured by considering the availability of the facility to its users and the variety of activities that it makes more accessible to pedestrians (or bicyclists).

1.1.3.1 Time Facility is Open for Use.

Situation	Points
Open at all times that facility is required	0
Open part-time for special purposes, e.g., lunch hours, school hours, daytime, peak travel hours, weekends, etc.	-2
Open part-time only for reasons indirectly related to the facility, such as when major stores are open or when there is (or is not) heavy traffic.	-6
Open only rarely, randomly, or irregularly	-10

TIME SCORE selected = ________

1.1.3.2 Accessibility.

Does the facility make pedestrian (or bicycle) travel more convenient to:

Transit	______
Parking	______
Transportation terminals	______
Bike routes	______
School or education centers	______
Recreation, historical, or cultural facilities	______
Medical facilities	______
Places of worship	______
Retail stores	______
Residential areas	______

ACCESSIBILITY SCORE is number of boxes checked = ________

1.1.3.3 Total Convenience Score.

Total CONVENIENCE SCORE is Time Score + Accessibility Score = ________.

1.3 Other Community Transportation

It is important to remember that pedestrian facilities are only one part of the city and, possibly, the region's transportation system. These two variables consider the impact of the pedestrian facility on the larger transportation and urban environment in which it is situated.

1.3.1 Adaptability to Future Transportation Development Plans

As a part of the overall planning process, expected future transit and highway developments should be considered to determine if they are likely to have a measurable effect on the facility. For example, plans for a pedestrian crosssing over a highway would certainly be changed if at a future date the highway were to be abandoned, relocated, or widened. Similarly, the design for a pedestrian tunnel would be different if plans existed for an underground rapid transit route crossing it.

This factor is intended to provide a judgmental rating for the adaptability of the proposed pedestrian facility to the present and planned transportation system. Based on all the information that is known concerning private and public growth plans for the future of the area, evaluate the adaptability of the pedestrian facility to future transportation and urban development plans on a scale from +10 to -10.

-10	-5	0	+5	+10
Requires significant modification to city or regional transportation plans to accommodate the facility		No significant effect on current or planned citywide or regional transportation system		Enhances planned future transportation system

FUTURE TRANSPORTATION PLANS SCORE selected = ________.

1.3.2 Impact on Use of Existing Transportation Systems.

Pedestrian and vehicle separation facilities may well have impacts on other transportation systems in the community. For example, vehicle or pedestrian rerouting might inconvenience bicyclists who had been accustomed to riding on uncongested routes. Transit lines might have to be rerouted, and buses might become overloaded in the vicinity of the pedestrian facility. Pupils' use of school buses might decline if the children can now cross a freeway safely or walk a shorter distance.

Figure A-8 is intended to be used as a worksheet to specify the extent and magnitude of the impacts. Place a check in each box that corresponds to an expected impact on the indicated mode. If the impact is major, use two checks. Add up the total number of checks on the bottom line.

2. Safety/Environment/Health

2.1 Safety

2.1.1 Societal Costs of Accidents.

The total societal cost of motor vehicle accidents involving pedestrians is a function of the number of accidents, their severity, and many direct and indirect costs such as medical and hospital, legal, income loss, pain and suffering, and insurance administration costs. This section provides a technique for estimating the relative risk of accident occurrence based on past experience of pedestrian, vehicle, environmental, and traffic control components. Multiplying the accident risk by the number of pedestrian exposures (in terms of pedestrian crossings of vehicle roadways), an estimate can be made of the number of accidents.

Transportation Systems	Change in Type of Use	Increase in Use	Noticeable Decline in Use	Modifications Required	Others
Bikeways					
Transit					
School buses					
Terminals					
Bus					
Railroad					
Airport					
Ferry					
Total					

Based upon the entries above, indicate on the scale below the degree of impact of the pedestrian facility on other community transport systems.

-10 -5 0 5 10

Very negative — Neutral impact — Very good

EXISTING TRANSPORTATION SCORE selected = ____.

FIGURE A-8

IMPACTS ON OTHER TRANSPORTATION SYSTEMS

Dollar value estimates for total societal costs can be developed using the data from this section and the techniques and cost data given in Chapter Two. The rest of this section describes how relative accident risk is estimated and then used to determine a unitless accident score for alternative pedestrian facilities.

The accident risk per crossing for each facility (or each crossing point affected by the facility if necessary) is estimated using the Accident Involvement Rate Adjustment (Figure A-9). For each crossing to be analyzed (one representative crossing may be evaluated if several similar crossings are involved), check off the boxes that apply, then sum the results for both present and planned conditions using the formula below the table to obtain Net Involvement Rates (NI Rate) for both situations.

Scoring Pedestrian Accident Costs. Unitless scoring for pedestrian accident costs is accomplished by computing a Comparative Crossing Risk for each situation by multiplying the annual number of crossings by the NI Rate (limited to a maximum of 2.0) for that situation and comparing by use of formula (14) below:

$$\text{Total COST OF ACCIDENT SCORE} = \frac{\left(\begin{array}{c}\text{present}\\ \text{number of}\\ \text{crossings}\end{array} \times \begin{array}{c}\text{present}\\ \text{NI Rate}\end{array}\right) - \left(\begin{array}{c}\text{proposed}\\ \text{number of}\\ \text{crossings}\end{array} \times \begin{array}{c}\text{proposed}\\ \text{NI Rate}\end{array}\right)}{\begin{array}{c}\text{maximum of above products}\\ \text{for all facilities being compared}\end{array}} \times 10$$

$$= \_\_\_\_\_\_\_. \qquad (14)$$

If this evaluation is being used to compare a number of sites, the maximum value indicated above should be the maximum Comparative Crossing Risk of all sites under consideration.

In the above formula (14), the numerator represents the difference between the number of accidents before the proposed facility (present), and after the proposed facility. The number of accidents for each case is obtained by multiplying the number of crossings by the NI Rate, computed using Figure A-7. The denominator is obtained by selecting the maximum number of accidents (either present or proposed), and dividing the difference in accidents for each individual site by this one number, the individual scores will be proportional to the number of accidents for each facility. For example, if Site A had a reduction of 10 accidents and Site B had a reduction of 5 accidents, the scoring for Site B would be only one-half of the score for Site A. If the denominator were 20, the score for A would be +5 and the score for B would be +2.5 (or rounded to +3). This formulation is used to maintain a level of comparability for the scores of several facilities.

	Number of:	Rate Decreases				Average		Rate Increases			
PEDESTRIAN	Elderly (≥65)	Few	10	5%	5	10%	0	20%	20	≥30%	40
PEDESTRIAN	Very Young (≤10)	Few	10	1%	5	2%	0	4%	20	>8%	40
PEDESTRIAN	Alcohol Involved	None	10	Few	5	Mod	0	Mod-High	20	High	40
PEDESTRIAN	Illegal Crossings	None	5	Few	3	Mod	0	Mod-High	10	High	20
VEHICLE	Average Vehicle Volume	Low	5	Mod-Low	3	Mod	0	Mod-High	5	High	20
VEHICLE	Average Vehicle Speed (mph) (kph)	<15 (<25)	5	15-24 (25-39)	3	25-30 (40-49)	0	31-40 (50-65)	10	>40 (>65)	20
VEHICLE	Turning Conflicts	None	5	Few	3	Mod	0	Freq.	5	Many	10
VEHICLE	One-way Traffic		–	Yes	3		–	No	5		–
ENVIRONMENT	Sight Distance	Good	4	Fairly Good	2	Fair	0	Poor	5	Bad	10
ENVIRONMENT	Crossings After Dark (Good Light)	Few	4	Mod-	2	Mod	0		–		
ENVIRONMENT	Crossings After Dark (Poor Light)		–		–	Few	0	Mod	10	Many	20
ENVIRONMENT	Weather	Mild	4	Mod-Mild	2	Mod	0	Mod-Severe	3	Severe	5
CONTROL	Signalization (Presence)			Ped & Veh	10	Veh Only	0	None	20		
CONTROL	Police Enforcement (Ped Laws)			Heavy	3	Mod	0	Light	3		
CONTROL	Active Public Education			Yes	2		–	No	2		

Sum the colums as indicated and divide each sum by 100:

Decreases ____/100 = ____ Increases ____/100 = ____

Net Involvement Rate is Increase Rate - Decrease Rate ________ + 1 = ________

Avg = Average
Mod = Moderate
Ped = Pedestrian
Veh = Vehicle

FIGURE A-9

ACCIDENT INVOLVEMENT RATE ADJUSTMENT

If only the present situation is being compared for a number of site, formula (15) below should be used for each site. This will provide a relative accident risk index (from 0 to -22.5 for comparing potential pedestrian improvement sites):

$$\text{relative accident risk index} = \frac{\text{present number of crossings} \times \left(\text{present NI Rate} - 0.2\right)}{\text{maximum number of crossings at any site}} \times (-10) = \underline{\qquad\qquad}. \tag{15}$$

<u>Example of the Use of Formula (14)</u>. Assume a four-block area of a street in a retail area closed lengthwise but with cross streets left open to motor vehicles. The street crossing locations are all similar and their before and after accident rates are:

Net accident involvement rate (present) = 1.45

Net accident involvement rate (proposed) = 0.85

The present and estimated future number of person crossings are:

Number of crossings (present) = 12,500 per day

Number of crossings (proposed) = 14,500 per day

$$\text{Total COST OF ACCIDENTS SCORE} = \frac{(12{,}500 \times 1.45) - (14{,}500 \times 0.85)}{\text{maximum of above products}} \times 10$$

$$= \frac{18{,}125 - 12{,}325}{18{,}125} \times 10 = \underline{+3.2 \text{ (or } +3)}$$

2.1.2 <u>Accident Threat Concern</u>.

This variable estimates the degree of anxiety caused by the perceived nature of conflicts between pedestrians and vehicles at conflict locations within the proposed facility or site. For all facilities where some degree of pedestrian/vehicle conflict exists, Figure A-10 is used. Appropriate values are checked, and sums computed as indicated. If separation between pedestrians and vehicles is complete, the score is +10.

		Positive		Average		Negative	
Vehicles	Traffic Volume	Low	2	Med	0	High	2
	Traffic Speed	Low	2	Med	0	High	2
	Turning Conflicts	Few	1	Mod	0	Many	1
	One-way Traffic	Yes	1	No	0		--
	Vehicle Mix		--	Mixed	0	High % Trucks Buses	1
Setting	Crosswalks	Marked	1		--	Unmarked	1
	Signalization	Veh and Ped	1	Veh Only	0	None	1
	Sight Distance	Good	1	Mod	0	Poor	1
	Lighting	Good	1	Mod	0	Poor	1

Sum the column values: Positive = ____ Average = ____ Negative = ____

Total ACCIDENT THREAT SCORE is Positive Sum - Negative Sum = _____

Med = Medium
Mod = Moderate
Ped = Pedestrian
Veh = Vehicle

FIGURE A-10

Accident Threat Concern Scoring

2.1.3 Crime Concern.

The variable components to be considered here are those that affect the perception of crime by both pedestrians and nearby residents and business persons. It is extremely difficult to predict the number and types of actual crime incidences that will be induced or averted by any particular facility. Wide variations in the physical settings of different facilities, the necessity to incorporate previous crime patterns near the facility location, and lack of specific research in this area

	Positive		Average		Negative			
Frequency of Visible Police Patrols	High	4	Mod	0	Low	4		
Pedestrian Density	High	4	Mod	0	Low	2	Very Low	4
Lighting	Good	3	Mod	0	Poor	4		
Visual Connection with Environment	View Outside	1	No View, Spacious	0	Narrow, Stark	2		
Line of Sight	Long	1	Mod	0	Short	1		
Communications	Pull Boxes, No Coin Voice	1	Coin Voice	0	None	1		
Community Awareness Programs	Active	1	None	0				
Vehicle Volume	Low	1	Mod	0	High	.5		
Idlers (drunks, panhandlers, teenagers)	Very Few	2	Few	0	Med	1	Many	2
Clutter (confusion, distaste)	Little	1	Some	0	Much	.5		
Litter	None	1	Some	0	Much	1		
Sum the column values:	Positive = ____		Average = 0		Negative = ____.			

Total CRIME CONCERN SCORE is Positive Sum + Negative Sum = ________ , ÷ 2 = ________.

FIGURE A-11

CRIME CONCERN SCORING

all contribute to these difficulties. Facilities that encourage large increases in the number of users may experience crime increases, particularly so-called "petty" crimes (such as vandalism and pickpocketing). However, reasonable enforcement levels can maintain or attain low crime rates in the area of pedestrian facilities if proper consideration of this variable is taken in the planning and design of the facility.

Fear of crime by the users and nonusers of the proposed facility can be estimated using the values of Figure A-11. Check the appropriate values and sum them to rate both the present and proposed facilities.

2.2 Attractiveness of Surroundings

The pleasantness of surroundings for a pedestrian may be measured in terms of pedestrian orientation of the environment, litter control, pedestrian density, and climate control and weather protection. The surroundings are much more important for pedestrian transportation than for other modes because the pedestrian interacts directly with his environment. Measurement techniques for these variables are described in the following sections.

2.2.1 Pedestrian-Oriented Environment.

Check off the boxes below that describe the facility being evaluated. For further commentary on planning attractive pedestrian environments, the reader is directed to Antoniou (1971), Benepe (1965), Morris and Zisman (1962), Nelson (1974), and Owen (1969).

Positive Impacts

Amenities

Small park or plaza	_____
Water fountain, artificial waterfall, or splashing water	_____

The Arts

Theater (open or enclosed)	_____
Mural(s) or other graphic art	_____
Sculpture	_____
Strolling musicians and performers	_____
Street artists, handcrafts	_____
Tasteful, unobtrusive background music in selected areas	_____

Buildings

Interesting architecture; creative entrances ____

Renovation, restoration, or good paint job ____

Communications

Attractive mailboxes ____

Attractive telephones ____

Clock or sundial ____

Exhibits

Exhibits, displays or demonstrations ____

Monument or statue ____

Nature

Trees ____

Gardens ____

Floral exhibits, with season variety ____

Songbirds ____

Outdoor Eating

Sidewalk cafes ____

Food pushcarts ____

Physical Comfort

Long, deep (30-inch), wooden benches ____

Steps or ledges on which to sit ____

Drinking fountains ____

Leaning posts (walls, pillars, flagpoles) ____

Retail Outlets

Street vendors (flowers, sundries) ____

Colorful or interesting shop fronts ____

Bookstore(s) ____

Newsstand ____

POSITIVE IMPACT SCORE is sum of boxes checked = ____

Negative Impacts

Caged pedestrian overpasses ____

Utility poles and wires ____

Automobile intrusion, extensive curb parking, parking lots, or garages ____

Long, monotonous frontages (such as factory or warehouse walls) ____

Vacant lots or buildings ____

Billboards or distasteful advertising ____

Long sections of tall (higher than 6 feet, 1.8 meters) fences ____

Narrow walkway ____

Noise ____

Motor vehicles or industrial odors ____

NEGATIVE IMPACT SCORE is sum of boxes checked

____ x 2 = ____

Total PEDESTRIAN ENVIRONMENT SCORE is Positive Impact Score - Negative Impact Score = ____, ÷ 2 = ____, -5 = ____.

2.2.4 Climate Control and Weather Protection.

This item considers heating, cooling, ventilation, and protection from the elements. Since outdoor facilities are rarely artificially heated or cooled, higher scores will occur on this variable for climate-controlled indoor facilities. Even indoor facilities that are not climate controlled provide some protection from the elements. For a discussion of traveler comfort with various heating, air conditioning, and ventilation conditions, see Cantilli (1972). However, there has been increased attention given to energy conservation since the time of Cantilli's research, and the ratings presented below place the optimum temperature in winter 4°F (2.2°C) lower than that in his thesis.

- Heating. In winter, to what temperature is the facility heated?

Temperature	Points
78°F (26°C) or warmer	2
73°F (23°C)	4
68°F (20°C)	5
63°F (17°C)	4
58°F (14°C)	2
53°F (12°C), or unheated	0

HEATING SCORE selected = ________.

- Air Conditioning. In summer, to what temperature is the facility cooled?

Temperature	Points
57°F (14°C) or colder	0
62°F (17°C)	2
67°F (19°C)	4
72°F (22°C)	5
77°F (25°C)	4
82°F (28°C)	2
87°F (31°C) or warmer	0
No artificial cooling	0

AIR CONDITIONING SCORE selected = ________.

- Ventilation.

Ventilation Rate or Condition	Points
Outdoor facility	5
2 ft^3 fresh air/minute/ft^2 floor space	5
1-1/2 ft^3 fresh air/minute/ft^2 floor space	4
1 ft^3 fresh air/minute/ft^2 floor space	2
1/2 ft^3 fresh air/minute/ft^2 floor space	0
No artificial ventilation	0

VENTILATION SCORE selected = _______.

- Protection.

Are pedestrians protected from

	YES	NO
Direct sun?	1	0
Gusts of wind?	1	0
Precipitation?	1	0
Blown rain coming in at a slant?	1	0
Snowdrifts or puddles?	1	0

PROTECTION SCORE is sum of values in boxes checked = ________.

Total CLIMATE AND WEATHER SCORE is Heating Score + Air Conditioning Score + Ventilation Score + Protection Score = ________, -10 = ________.

2.3.4 Conservation of Resources.

Precise identification of all resources involved in the construction, maintenance, and use of a pedestrian facility would be an extremely time-consuming process unnecessary for the intent of this methodology. The scoring system presented is devised primarily to distinguish between alternatives, and a checklist of resources utilized relative to their scarcity is the indicator to be used.

Five major categories of resources were considered; the most significant elements in each category relative to pedestrian facilities were identified. They are:

- Energy resources (direct)--crude oil and related products; natural gas; hydropower; and coal.
- Manufactured materials (indirect energy use)--metals and metal products; lumber and wood products.
- Natural resources (nonenergy)--water supply; soil quality, stability and contour.
- Human resources--labor.
- Private and public services--sanitary services, communication services (transportation services are considered separately in Sections 1.1 to 1.3).

An estimate of the use should be made for each major resource category relative to the reviewer's concept of "ordinary" use of the resource in general pedestrian facilities. If very little use of a resource is made, check the box labeled Low for that resource. If the amount of a resource category used seems significantly higher than comparable pedestrian facilities, check the box labeled High. Otherwise check the box labeled Mod (for moderate). The internal weights of resource categories below indicate the relative availability, renewability, or reusability of the resources considered.

	Positive		Negative
Direct energy	Low 4	Mod 0	High 4
Manufactured materials	Low 3	Mod 0	High 3
Natural resources	Low 1	Mod 0	High 1
Human labor	Low 1	Mod 0	High 1
Services	Low 1	Mod 0	High 1

Sum the columns: Positive = _____ Negative = _____

Total CONSERVATION SCORE is Positive Sum - Negative Sum = ________.

3. Residential/Business

3.1 Residential Neighborhoods

The final score for residential relocation is obtained by formula (18) below:

$$\text{Total RESIDENTIAL DISLOCATION SCORE} = \text{Circumstances index} - \frac{\text{Reimbursement index} \times \text{Household index}}{10} \quad \text{index} \qquad (18)$$

The following descriptors are used to illustrate the scoring method.

- 15 households impacted.
- 50% reimbursement policy for household goods movement and living expenses.
- No reimbursement for other costs (renovation, and so forth).
- Good housing program to assist home owners in finding reasonable dwellings (also at moderate cost for low income families)

Household index = 4

Reimbursement index = 6.5

Circumstances index = 5

$$\text{Total score} = 5 - \frac{6.5 \times 4}{10} - 4$$

$$= 5 - 2.6 - 4$$

$$= -1.6 \text{ (or rounded to } -2)$$

3.1.2 Community Pride, Cohesiveness, and Social Interaction.

This variable considers the impacts of proposed pedestrian facilities on neighborhood and community attitudes and personal relationships among residents. These impacts are difficult to assess, in part because of the wide diversity of neighborhood types. A frequent assumption in the past has been a relative homogeneity of neighborhoods; however, in recent years this has been seriously challenged (Lehmann et al., 1974; Warren and Warren, 1975).

Variations of values and interactions within and between neighborhoods strongly suggest survey or interview techniques to adequately assess the impacts of proposed facilities (Kaplan et al., 1972; Ryan et al., 1972). These techniques provide data that cannot be efficiently obtained in any other way, but care must be taken to minimize measurement errors in such data (Lehmann et al., 1974). Detailed attitudes about the proposed project, attitudes toward the community, and the nature of friendship and social interaction patterns can all be examined, as well as attitudes toward alternative proposals.

Probably the most important assessment to be made in evaluating community impact is what degree of adaptation in behavior will be required as a result of the facility. The scoring system presented here is designed to assist in identifying the types of changes that may be caused by a pedestrian facility, and the degree of desirability of such changes.

The researcher should feel free to reassess the relative magnitude of individual changes by modifying the internal weights of each component. These weight modifications should be scaled to keep within the range of +10 to -10.

A total score for this variable is obtained using Figure A-19. The type of impact is assessed and checked for a list of variable components, then the rating columns are summed. The total score is the sum of the favorable points minus the sum of the points for unfavorable outcome.

	Rating		
Component	Favorable or Improved	No Change	Unfavorable or Decline
Interest expressed in project	1	0	1
Access to neighbors and friends	1	0	1
The pedestrian facility as a meeting place	1	0	1
Neighborhood communications (e.g., bulletin boards)	1	0	1
Access to community facilities (e.g., shopping, theaters)	1	0	1
Links to rest of community	1	0	1
Activities planned (e.g., block parties)	1	0	1
Protection of privacy	1	0	1
Fewer motor vehicles	1	0	1
Bicycle/jogging paths	1	0	1

Sum the columns as indicated: Favorable = _____ Unfavorable = _____

Total COMMUNITY PRIDE AND INTERACTION SCORE is
Favorable Sum - Unfavorable Sum = ________.

FIGURE A-19

NEIGHBORHOOD/COMMUNITY IMPACTS

3.1.3 Aesthetic Impact, Compatibility with Neighborhood.

This variable is used to assess the blending of a proposed pedestrian facility with the physical surroundings of a residential neighborhood. It should only be considered when pedestrian facilities are located in residential areas (for example: sidewalks, paths, pedestrian/bicycle networks).

A checklist of favorable components (Figure A-20) is followed by a checklist of unfavorable ones (Figure A-21). The points in each checklist are to be added separately and then combined by subtracting the unfavorable point sum from the favorable point score. Nonapplicable points for a specific facility should be ignored (automatically assigning a neutral value of 0 to that component).

Structure and shape complementary to neighborhood architecture style	_____
Pleasing and complementary colors or textures	_____
Unobtrusive grade change features (ramps and steps should be masked if possible)	_____
Continuity of pathway with existing pedestrian paths	_____
Blended signing with nor glare lighting	_____
Overall lighting complementary to existing light features and intensity levels	_____
Continues existing bicycle/jogging paths	_____
Reduced motor vehicle traffic	_____
Compatible noise levels; 50-55 db(A) in many neighborhoods	_____
Residential privacy protected	_____

Sum of positive components = ________

FIGURE A-20

POSITIVE COMPATIBILITY COMPONENTS

Unpleasant contrast between facility and existing architecture style	_____
Displeasing color or texture contrast	_____
Little pedestrian path continuity	_____
Obtrusive signing	_____
Uncomplementary lighting and fixtures compared to existing features	_____
Increased motor vehicle traffic, especially trucks	_____
Increased noise level--over 55 db(A)	_____
Privacy or sleep disturbed by users	_____
Additional litter or vandalism	_____
Fences, poles, or wires	_____

Sum of Negative Components = ________

Total AESTHETICS AND COMPATIBILITY SCORE is
Positive Sum - Negative Sum = ________.

FIGURE A-21

NEGATIVE COMPATIBILITY CHARACTERISTICS

3.2 Commercial/Industrial Districts

The implementation of many, if not most, pedestrian facilities vitally concerns the affected business interests in the vicinity. Not only long-term benefits, but survival during the construction and transition phase of the project, are major considerations, especially for small local business persons. This section directs special attention to short-term (i.e., 1 to 5 years) effects on business enterprises from implementation of a pedestrian facility, with the highest ratings assigned for those plans estimated to have the least detrimental effect.

3.2.1 Gross Retail Sales.

The change in gross sales from last year's performance for the period under question is probably the single most important evaluation criterion for any retailer. Even though different stores will operate at different profit margins, and any increase in sales is likely to be more profitable than average (since the fixed expenses of rent, utilities, and some or all of the payroll have already been recovered), retailers still prefer to evaluate only the change in gross sales. This often reflects business people's reluctance to allow any useful information to get into the hands of competitors. Frequently, however, the store owners are unsure of their actual marginal rate of profit because of the complexity of its determination.

Changes in gross sales result from improved customer access, a greater volume of pedestrian traffic passing the store, improved attractiveness of individual stores or the general area, and changes in the number of visitors, including out-of-town tourists. Individual store owners should be asked to estimate the effect of the facility on their businesses, although they may be reluctant or unable to do so without a trial experimental street closure. While temporary or trial solutions lack many of the amenities of a permanent installation (such as attractive walking surfaces, trees, benches, and fountains), they can provide an indication of the public and business acceptance of the concept.

A more dependable source for estimates of changes in sales would be a large department store (often part of a chain) that has a research or statistics department, particularly if it has assembled data from previous experiences with similar projects. A chamber of commerce or merchants' association may be able to supply some data, but usually it will direct you to an executive of the major retailing firms, who will be the ultimate source of information.

One rule of thumb has been developed based on the experience of Norwhich, England in 1967 (Wood, 1970) and Kalamazoo, Michigan in 1959 (Elliot, 1964) relates the increase in sales attributable to a successful facility (change in sales for the affected stores minus the change in sales for the region) to the increase in pedestrian traffic on the mall. Retailers know that sales are directly proportional to foot traffic, and from these two examples the ratio of changes in sales to changes in foot traffic was found to be about 1 to 10. For Norwich, there was a 5% improvement in sales that could be attributed to the street closure, and a 45% increase in pedestrian traffic. Gross sales in downtown Kalamazoo for 1959, the first year after the mall was completed, increased 15%. Retail sales for the county increased 12% for that same period, so the sales increase attributable to the mall is 3%. Pedestrian traffic on the mall increased 30%.

Experience also shows that the rate of sales increases is likely to be limited to the first few years of a mall's existence because the novelty of the installation wears off and another sales attractor will probably be introduced into the region. Stone and Surti (1975) assume that the first five years' increase in sales declines uniformly to zero over five years. In their example, a mall built in 1975 would account for a 15% sales increase for 1976 over 1975, 12% over 1977 over 1976, 9% for 1978 over 1977, 6% for 1979 over 1978, 3% for 1980 over 1979, and 0% for 1981 and subsequent years. Since sales are not expected to decrease beyond the five-year projection period, the sales increases in the first year and subsequent four years build an increased sales base, attributable to the mall, that should continue for years into the future.

This theory can be supported, rather than its contra-theory which is that there would be a decline in sales, because historically, malls have proved to be a stimulus for new construction and investment after they have been in operation for a number of years. It seems most likely that the first year will account for a big surge, and so it is best to consider that year a settling-in period, and try to estimate the average annual percentage increase in gross retail sales over at least the first two years of operation of the facility. Of course there will continue to be an increase in sales resulting from the pedestrian facility after the first two years, but it is felt that the experience of the first two years is sufficient to characterize the impact of the facility on gross sales.

In summary then, estimate as accurately as possible the average annual change in retail sales attributable to the pedestrian facility for the first two years. This will be equal to the sales change for the affected stores minus the regional average for the same period. Use this percentage as the retail sales score. Since we are using a -10 to +10 scale, indicate as -10 any two-year annual increase in sales greater than 10%. If projections indicate an expected sales volume decrease of greater than 10%, serious consideration should be given to alternatives with less severe impacts on local merchants and business persons.

It is expected that the projection of gross retail sales will be assessed at one time for the area affected by the facility as a whole, rather than scaling up from estimates from particular stores or groups of businesses. However, when the shopowners are contacted to determine their displacement or renovation costs for evaluating variable 3.2.2, they may be asked about their estimates of changes in gross sales, and this may be used as input to this estimation process.

RETAIL SALES SCORE selected = ________.

3.2.3 Ease of Deliveries and Employee Commuting.

A significant purpose of a shopping mall or commercial district is to increase the flow of merchandise into and out of the area; hence, the ease of deliveries to an area is important. The flow of goods out of the area is usually handled by the pedestrians, particularly in downtown locations.

There are three major methods of truck deliveries to downtown businesses and other freight receivers. One is via the utilization of off-street loading docks; another is on-street curb parking immediately adjacent to a rear door or side door to the store or building; and the third is on-street curb deliveries using the front customer entrance. Each of these will be affected differently by motor vehicle traffic restrictions.

Off-street loading docks can be found at very large freight attractors such as large department stores, hotels, and office buildings. They are preferable to other forms of goods delivery because conflicts between trucks and pedestrians or other motor vehicles are greatly reduced or eliminated. Therefore, if the facilities affected by motor vehicle restrictions have off-street loading bays, they will not be impacted by the restrictions (unless they apply to the street on which the approach to the loading dock is located) and thus they score a "0" for no gain or loss. If the addition of off-street loading areas is included as part of a new building under construction concurrently with the pedestrian facility, then it would merit +10 because it is a big improvement. On the other hand, if an off-street loading dock were required to be added to an existing building that does not now have one, it should score -10 because of the much greater expense of retrofitting, when compared with building the facility into the building from the beginning.

If there is now on-street curb parking, there may be priority parking for trucks, no special provision for truck parking, or illegal truck parking and standing. If curb deliveries will still be permitted, and the parking regulations remain the same, then score "0" because there is no gain or loss, unless there is significant interference with sidewalk pedestrian traffic. If parking regulations are changed to make deliveries easier, score +5. An example of this regulation would be the establishment of a truck loading zone with commercial vehicle parking only between 7 a.m. and 7 p.m. Similarly, score -5 if parking regulations and access are changed in a manner that makes deliveries significantly more difficult.

If motor vehicle traffic is prohibited during all or part of the day on a street, then stores that receive their deliveries on that street will have to make other arrangements. Deliveries may be permitted only during certain hours of the day, depending on local conditions--store hours, office hours, and peak-hour congestion. This might require certain adjustments on the part of receivers and the trucking companies due to labor contracts and security considerations. However, over the long run, adjustment may be more efficient since there would be no vehicle congestion to compete with delivery trucks, and store personnel could be organized to receive goods for a few specified hours per day. Smaller stores are affected by changes in the hours of deliveries more than larger stores, since the person needed to receive the goods represents a significant fraction of the labor force for a small store. The score for this situation might range from +2, reflecting more efficient deliveries, as described above, to -8 if there were a major inconvenience and significant cost for most truckers and receivers.

Truckers are likely to benefit from changes in the hours of deliveries at the expense of the receivers. Also, as noted above, different stores will be affected differently by changes in regulations. If this is the case, a table should be constructed which shows the benefits or disbenefits to each stakeholder on a scale from +10 to -10. These should be combined, using appropriate weights, to arrive at an aggregate score. For example, consider a simplified situation with two stores and a trucking firm that serves both of them. If the big department store benefits slightly from the change of delivery hours (+2), the small shop is severely inconvenienced (-8), and the trucking firm benefits (+6), the net score would be zero if all three were weighted equally. If the small shop were given more weight, the net result would be a disbenefit, whereas if the trucker or the large store were weighted more highly, the net result would be a positive benefit.

An alternative to restricting truck traffic to certain hours is to prohibit it at all times, in which case the drivers would have to park on the nearest street and transport the goods to the store by hand or with a dolly. This could be a significant problem if there are heavy, bulky, or frequent deliveries. Trucks would usually be parked out of the view of the driver, so they might have to be locked where they were not previously. A special case is currency shipments to and from banks by armored car. If the courier must walk with money any distance away from his truck, then there is a company rule that he must walk with his gun drawn. This will detract from the atmosphere of the mall, so it is suggested that armored cars be made exempt from restrictions that apply to other trucks. This has been done on the Sparks Street Mall.

	Possible Score	Actual Score (leave blank if not applicable)
Facilities have off-street loading arrangements	0	
Off-street loading areas are to be added:		
For new construction	+10	
For existing buildings	-10	
Parking regulations:		
Remain the same	0	
Changed to make deliveries easier	+5	
Changed and make deliveries more difficult	-5	
Restriction of truck deliveries to certain hours	+2 to -8	
Outright prohibition of trucks	-5 to -10	
Above, but with local consolidated delivery centers	-5 to +5	
Inconvenience to employee commuters	0 to -5	

Total DELIVERIES AND COMMUTING SCORE is sum of values scored above = __________.

If sum of values exceeds +10, score +10.

If sum of values is less than -10, score -10.

FIGURE A-23

URBAN GOODS MOVEMENT POINT ALLOCATION

The score for an outright prohibition of trucks, requiring truck drivers or receivers to use handcarts for goods to be delivered to stores, will range from -5 to -10, depending on the distances involved, frequency, and nature of deliveries. An alternative to accommodate outright prohibition of trucks would be the establishment of local consolidated delivery centers that would receive shipments for all affected buildings, and deliver the goods manually or mechanically (such as an underground conveyor belt system) to the ultimate receivers. Colorful carts could be used on the mall, and goods could be stored up to a day or two at the central facility, so the actual deliveries could be made at a time most convenient to the shop owners, taking into account pedestrian traffic volumes. Once this facility were established, it could prove to be a net benefit, perhaps with a score of +5, depending on its operating costs and success.

It is not expected that a pedestrian facility will cause inconvenience to employees who commute to the site, since pedestrian access will be improved. However, lack of parking or other inconveniences might cause difficulty in attracting and retaining employees for some employers. If this case holds, subtract up to five points from the ease of delivery score to reflect any special problems for employee commuters. Figure A-23 recapitulates the suggested scoring for this item.

3.2.4 Attractiveness of Area to Business.

Check off the proper boxes below.

	YES	NO
Is there a significant rise in the rate of voluntary improvements to the property?	2	0
Is there a trend toward the acquisition of additional selling and storage space?	2	0
Is there a low vacancy rate for stores?	2	0
Is there expressed interest by out-of-town firms to move into the area of the pedestrian facility? (This may be measured by the volume of inquiries to the Chamber of Commerce or the local economic development administration if there is one.)	2	0
In addition to advertising for individual stores, do the merchants publicize the area surrounding the pedestrian facility as a place to go to shop?	2	0
Do the merchants show enthusiasm for the area as a place to do business?	2	0

Are there informative, educational, or entertaining displays in store windows or in hotel and office lobbies?	2	0
Are there any special promotional activities sponsored, such as car displays, boat shows, or sidewalk sales?	2	0
Is there a feastive atmosphere, making the area pleasant for shopping?	2	0
Can many out-of-towners be found among the consumer foot traffic?	2	0

Total ATTRACTIVENESS TO BUSINESS SCORE is sum of values checked above = _______ - 10 = _______.

4. Government and Institutions

4.1 Transportation and Land Use Planning Process

4.1.1 Public Participation in the Planning Process.

Societal attitudes and recent legislation have changed the role of the planner from one who works in relative isolation from the public as a whole, except perhaps for vocal private interest groups, to one who must solicit and obtain public input on current transportation projects that are in the planning and design phase (Yukubousky, 1974).

The public has become to a large extent wary, if not downright skeptical, of public decisions made in closed sessions outside of wide public discussion and has in effect "demanded" more voice in those decisions. This wariness is based upon a confluence of three central emerging factors:

- The emerging recognition by minority groups of their potential political power through organization and outspoken advocacy for minority-related issues.
- The recognition of a widespread abuse of public decisionmaking power for the benefit of a privileged few.
- The importance of the environmental protection movement as reflected in a wide variety of special interest organizations.

If one accepts these precepts, then the inclusion of public participation in public decisions is seen not so much as an inherent "good," but as essentially a political necessity. For example, it is entirely feasible that a public decisionmaking body could make decisions that had overwhelming public support without holding extensive public meetings and hearings. The degree of this public support has typically been based upon "voting" records for funding specific proposals, and of course, for election of public officials. Over the past several years, the voting has more and more frequently rejected proposed bonding proposals and as a consequence has "forced" widespread public participation in the planning process as a practical necessity for their successful passage.

The current planning situation effectively requires a deliberate process for extensive public participation, and as a consequence of that realization we have provided a criterion to predict "in advance" the probable adequacy of that participation. In situations where comparisons of alternative pedestrian facilities for one site are under consideration, presumably the same planning process would apply to all, and this variable would then be logically dropped. Where different planning processes were in effect in different locations of a jurisdiction (for example, where local option determined the planning process), then this variable would rate the most extensive public participation an inherent "good" and accordingly place it higher on the rating scale.

Figure A-24, which is adapted from Yukubousky (1974), describes a wide variety of community interaction techniques ranging from zero public participation to a high degree of community input. Some of the techniques that might involve the public to a major degree might, at first, seem inappropriate for simple pedestrian facilities, having been designed for preparation of comprehensive metropolitan and regional transportation plans. However, broad community participation is felt to be important for small projects also; therefore, the scale described in Figure A-24 is equally applicable to both small and large projects.

Since the primary purpose of the methodology described herein is evaluation, excluded from the discussion is an analysis of the significant roadblocks to achieving genuine levels of participation and increased input. For a holder of political power, these include inadequacies of the political socioeconomic infrastructure and knowledge base plus extremes of self interest that do not allow proper consideration of the rights or needs of others. For further discussions of public participation in the planning process, the reader is directed to Yukubousky (1974), Manheim et al. (1975), Grigsby and Campbell (1972), and Fitzpatrick and Miller (1973).

Actions of Implementing Agency	Point Score
Monitor newspapers, radio, and television	-10
Conduct background studies and review election issues	-9
Catalog planning and design concepts	-8
Monitor impacts of complicated projects	-7
Initiate legislation	-6
Produce material for the media	-5
Present range of alternatives to public	-4
Map socioeconomic and attitudinal data	-3
Illustrate plans in nontechnical terminology	-2
Educate public about ongoing planning and decision-making process	-1
Maintain open planning and project files; listen to the public for suggestions	0
Survey opinions and attitudes	+1
Hold public hearings early in the planning process, with widespread publicity at least one month in advance of each meeting	+2
Hold a citizen referendum, to ensure draft plans will incorporate the majority opinion of the community	+3
Assemble a panel of community residents assisted by planners to make recommendations on alternative proposals at community meetings	+4
Set up community-led seminars	+5
Use a citizen advisory committee. Request a written review of all draft plans and alternative suggestions	+6
Mediate between parties	+7
Appoint a task force	+8
Hold workshops or informal neighborhood work meetings	+9
Employ community residents for brainstorming sessions, ombudsmen, and role playing	+10

PUBLIC PARTICIPATION SCORE selected = ________.

FIGURE A-24

RATING SCORE FOR COMMUNITY INTERACTION TECHNIQUES

4.2 Economic Impacts

4.2.1 Net Change in Tax Receipts and Other Revenue.

Changes in government revenues can be estimated in dollars by the planner with inputs from appropriate government agencies.

Sales taxes are usually collected by the state and partially reimbursed to the cities (or sometimes vice versa) and thus gross receipts data are available from the collection agency. Data are categorized by the state of sale and are considered confidential, but they should be available on an aggregate basis, either for geographic units or by type of business.

Corporate income statistics can be obtained from the state or federal revenue collection agencies on a countrywide basis, which covers too wide an area for our purpose. However, geocoding programs of 1970 census data in some states have made it possible to measure data by city cells. These data are confidential, under the control and security restraints of the government, but are accessible on a contractual basis.

Change in assessed property valuation and hence property tax revenues may be estimated by the assessment office of the city or county government. If this total change is X%, it is assumed that it occurs at a rate of X%/5 for the first 5 years and then remains at the resulting level for the next 20 years, making a total planning horizon of 25 years. According to data collected by the Downtown Research and Development Center (1974) for Kalamazoo, Knoxville, and Pomona, X can range from 20% to 75%.

The change in revenue from pedestrian moving violation fines may be determined upon consultation with the appropriate judicial system.

If the pedestrian facility were strictly a business investment on the part of a municipal government, this variable would be the most important evaluation criterion. However, other motivations (i.e., the other variables) are likely to be more significant. Further, tax receipts and other government revenue resulting from a particular pedestrian facility will be mixed with other general revenue, not specifically earmarked to defray the facility's operating and construction costs. Thus the magnitude of additional revenue can be compared with the government's total budget rather than merely with the expenditures for the pedestrian facility. For a small city within a metropolitan area, a major new shopping/commercial pedestrian facility might generate municipal revenue as much as 10% of the city budget, although in most cases it will be a smaller fraction. Ten percent will be used to set the endpoint of the scale for this variable.

To evaluate this variable, estimate as accurately as possible the average annual change in sales, corporation income and property tax receipts, parking, motor vehicle, and pedestrian violation fines, and other government revenue attributable to the pedestrian facility for the first two years. The annual average over a two-year period is taken to compensate for the first year's settling-in period, as is done for retail sales in 3.2.1. Divide this annual change by the total city budget, exclusive of the pedestrian facility. When expressed as a percentage, the number will be equal to the rating for this variable. Since +10 is the maximum scale value, indicate as +10 any increase in revenue of more than 10%. If a decline in total municipal revenues is greater than 10%, discussions should be held to examine alternatives with less serious revenue impacts.

TAX RECEIPTS SCORE selected = _______.

4.3 Community Impacts

4.3.1 Community Activities.

The demand for community activities such as displays, exhibits, special events, recreation, arts and crafts festivals, and fund-raising drives can serve as an indicator of the attractiveness of the area and city in which the pedestrian facility is located. An increase or decrease in the number of such activities will show changes in public participation in the community. While permits are the source for monitoring this type of activity, they are necessary only if the event occurs on city property or if a street closure or sidewalk obstruction is required. Many of these events take place on private property and do not require official sanction. Peddlers, solicitors, and auction licensing may be another source of monitoring.

Records of community activities are available from local police departments and licensing departments. However, files are not longstanding and are frequently destroyed on expiration dates or immediately thereafter. Forecasting the change in such activities is an extremely subjective undertaking unless representatives of community groups that sponsor the activities have been involved in the planning process.

Indicate the score for change in community activities on the scale below:

-10	0	+10
Large decrease in community activities	No change in community activities	Large increase in community activities

COMMUNITY ACTIVITIES SCORE selected = _______.

4.3.2 Adaptability to Future Urban Development Plans.

The adaptability of the pedestrian facility (as a transportation link) to future transportation system development plans is covered in item 1.3.1. However, many facilities, particularly those designed for the purpose of providing a safe and enjoyable place for pedestrians to move leisurely and stop, impact the land uses in the vicinity as much or more than they affect the transportation system. The degree to which the facility fosters or hinders planned land uses for the area is measured by this variable.

As an example, consider a downtown pedestrian mall. Although a pedestrian mall may introduce a revitalization to a downtown area, alone it might be insufficient to save a city that has already gone into decay. If businesses will be moving out of the area with no replacement, then there will not be any pedestrians left to enjoy the mall.

Evaluation of the impact of the facility on planned development can be performed best by an urban planner responsible for the area in question. Indeed, if the facility has been proposed by the planning or development agency having jurisdiction over the area, then there is assurance that the facility's operation will conform with long-term development plans for the area. Unless there is in-house struggling, the score for this situation would be +10. For other conditions, the rating should be assigned accordingly.

-10	-5	0	+5	+10
Requires significant modifications to existing land use and development to accommodate the facility		No significant effect on short- or long-term land use and development plans		Enhances desired land use and growth patterns

FUTURE URBAN PLANS SCORE selected = ________.

SUPPLEMENT 17

FACILITIES COSTING - EXAMPLES AND ADJUSTMENT DATA

17.1 Comparative Cost Analyses of Specific Facilities

Several simple comparative analyses of selected facilities are presented below. Comparison is based strictly on cost elements as defined in Step 26.5.2; this is a valid means to evaluate alternatives if an assumption is made that the alternatives are all equally effective. In most cases, utilization not withstanding, they are equally effective. No attempt has been made to introduce detailed locational contingencies, although note is made of their possible impact where applicable.

17.1.1. Highway Crossings

For cost estimating purposes, an eighty-foot crossing for an at-grade highway, including lighting and drainage, where applicable, is assumed. Various options and their respective unadjusted construction costs are shown in Table 17-1. Based on the results in Table 17-1, it would appear that the minimum costs are associated with the conventional cast-in-place concrete overpasses. However, it is possible that traffic flows may be impeded during construction; related cost would have to be taken into consideration. With regards to the comparison between overpasses and underpasses, the cost decision clearly favors overpasses, except in the case of a cut and fill facility built in conjunction with new highway construction.

17.1.2. Street Crossings (CBD)

The grade-separated facilities assumed for a cost estimating example cross an existing urban, CBD street. The systems are 12 feet wide, enclosed, with an eighty-foot span. The cost of penetrating existing buildings is not included. The results are shown in Table 17-2. As the results indicate, the elevated walkway system built using conventional construction methods appears to be the most economic solution. The cut-and-cover underpass would incur substantial additional site specific costs, as would the tunnel. This comparison gives some insight into the cost of aesthetics as well, since the lower cost walkway systems also are probably the least aesthetically pleasing.

TABLE 17-1

CROSSINGS COST COMPARISON

OPTION NUMBER	FACILITY TYPE	MATERIAL AND CONSTRUCTION METHODS	NUMBER OF SPANS	NUMBER OF PIERS	NUMBER OF MEDIANS	TERMINAL CONNECTORS	UNADJUSTED CONSTRUCTION COST
1	Overpass	Conventional Steelwork	1-80'	2	0	Stairs	$ 81,771
2	Overpass	Conventional Steelwork	1-80'	2	0	Ramps	91,782
3	Overpass	Conventional Steelwork	2-40'	4	1	Stairs	86,588
4	Overpass	Conventional Steelwork	2-40'	4	1	Ramps	96,458
5	Overpass	Conventional Cast-In Place Concrete	1-80'	2	0	Stairs	66,543
6	Overpass	Conventional Cast-In Place Concrete	1-80'	2	0	Ramps	76,554
7	Overpass	Conventional Cast-In Place Concrete	2-40'	4	1	Stairs	71,670
8	Overpass	Conventional Cast-In Place Concrete	2-40'	4	1	Ramps	81,631
9	Overpass	Precast Concrete	1-80'	2	0	Stairs	68,461
10	Overpass	Precast Concrete	1-80'	2	0	Ramps	78,472
11	Overpass	Precast Concrete	2-40'	4	1	Stairs	75,167
12	Overpass	Precast Concrete	2-40'	4	1	Ramps	85,178
13	Underpass	Cut and Fill; New Road					87,758
14	Underpass	Cut and Fill; Existing Road					131,412
15	Underpass	Tunnelling; Existing Road					230,112

OPTION NUMBER	FACILITY TYPE	MATERIAL/ CONSTRUCTION METHODS	ADJUSTED CONSTRUCTION COST
1	Elevated Skyway	Conventional Steel, Enclosed, Heated and Air Conditioned	$ 122,952
2	Elevated Skyway	Conventional Concrete, Enclosed, Heated and A.C.	$ 107,611
3	Elevated Skyway	Steel Truss, Enclosed, Heated And Air Conditioned	$ 228,758
4	Underpass	Cut-and-Cover, Existing Street	$ 131,412
5	Underpass	Tunnel, Cast-In-Place, Concrete	$ 230,112

TABLE 17-2

COMPARISON OF VARIOUS STREET CROSSINGS COSTS

17.2 Geographical And Temporal Adjustments

When compiling facility cost data for comparison or as preliminary estimates, it may be necessary to make certain adjustments to cost elements in order to account for geographical or temporal differences. When the unadjusted construction cost computed in Subsection 5 of Step 26.5.3 is adjusted for geographical and/or temporal differences, it will be referred to as the adjusted construction cost.

17.2.1 Geographical Differences

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

The 1978 Dodge Manual for Building, Construction Pricing and Scheduling 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.

Use of the Dodge locality adjustment factors is illustrated in Figure 17-1.

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

WHERE:

C_A = Value of Cost Element in Location A

C_B = Value of Cost Element in Location B

F_A = Locality (Dodge) Adjustment Factor for Location A

F_B = Locality (Dodge) Adjustment Factor for Location B

---

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

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

(2) To Adjust Estimates Obtained Using the Cost Factors Provided in Sections 26.5.2 and 26.5.3. (Base and Specific Costs) for Location A, Compute:

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

FIGURE 17-1

USE OF THE DODGE LOCALITY CONSTRUCTION COST ADJUSTMENT FACTORS

17.2.2 Temporal Differences

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

Table 17-3 outlines "Regional Inflationary Trends - 1959-1976" and is designed to permit the conversion of cost estimates developed at different points in time and in different regions to comparable costs in

1976 dollars for one specific region. For example, the tabulation of building costs indices can be employed to adjust the average 1976 vs. cost data provided in Step 26.5.2 to reflect geographical and temporal differences of known inflationary factors in specific regions of the country. The procedure for cost adjustment is described in Figure 17-2.

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

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

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

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

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

FIGURE 17-2

USE OF THE ENR BUILDING COST INFLATION FACTORS

	U. S. Average	ATLANTA	BALTIMORE	BIRMINGHAM	BOSTON	CHICAGO	CINCINNATI	CLEVELAND	DALLAS	DENVER	DETROIT	KANSAS CITY	LOS ANGELES	MINNEAPOLIS	NEW ORLEANS	NEW YORK	PHILADELPHIA	PITTSBURGH	ST. LOUIS	SAN FRANCISCO	SEATTLE	MONTREAL	TORONTO
1959		83	87	86	81	78	84	78	81	83	81	85	80	83	84	81	86	82	84	74	79	78	90
1960	77	84	87	88	83	79	85	79	87	84	82	85	82	84	84	81	88	85	84	74	80	79	81
1961	79	84	87	90	87	80	87	80	88	86	83	86	84	85	85	84	87	86	85	76	82	78	82
1962	81	87	87	91	88	82	88	81	90	87	85	88	86	86	87	86	89	88	88	81	85	80	83
1963	84	90	90	94	92	87	91	84	98	89	88	90	89	88	89	88	91	91	91	85	88	82	84
1964	87	94	91	96	92	93	93	87	94	90	87	92	91	91	92	91	92	93	93	86	90	84	87
1965	91	99	93	95	92	93	100	92	97	91	92	95	91	88	94	95	95	91	95	92	94	84	88
1966	95	98	99	99	97	97	99	96	102	94	97	98	95	93	98	96	98	92	97	96	97	97	98
1967	100	103	102	103	102	102	106	105	104	98	103	102	100	97	102	101	101	98	101	103	102	103	104
1968	108	115	111	111	112	109	121	119	114	113	112	108	110	106	114	112	114	113	111	112	113	107	111
1969	119	120	119	115	119	117	131	126	121	114	126	116	113	116	121	117	123	114	117	112	119	125	117
1970	130	127	130	117	128	125	140	137	126	124	133	153	122	126	130	125	137	125	124	125	127	124	124
1971	148	149	158	142	147	143	168	156	143	146	150	153	144	146	142	152	161	149	140	145	142	129	138
1972	164	166	167	156	163	153	175	165	160	160	160	168	165	156	152	162	170	163	154	160	152	137	163
1973	177	173	183	165	175	165	190	172	170	167	169	180	173	164	169	172	183	167	161	168	165	158	172
1974	188	181	181	180	187	176	207	187	177	179	183	195	185	177	180	185	195	178	173	187	184	186	180
1975	206	194	203	195	204	188	217	201	192	197	198	214	202	191	198	199	215	190	190	203	206	199	206
1976	220	216	225	219	220	206	232	218	216	217	215	233	238	209	219	216	228	208	207	227	227	219	266
1977	238	231	238	234	245	226	258	231	235	241	231	256	263	229	241	231	239	226	225	238	245	242	251
1978 (May)	247	243	248	245	242	228	265	236	244	246	240	269	264	234	251	236	246	232	233	275	256		

SOURCE: Regional Inflationary Trends 1959-1976
ENR Building Cost Index History 1913 - 1976 - Base Year 1967 = 100

FIGURE 17-3

REGIONAL INFLATIONARY TRENDS

☆U.S. GOVERNMENT PRINTING OFFICE: 1979 O— 629-948 2440 REGION 3-1

FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

---

* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD-2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.