STRUCTURING AN ANALYSIS OF PEDESTRIAN TRAVEL

Michael J. Demetsky and David Morris, Department of Civil Engineering,
University of Virginia

Pedestrian characteristics and physical elements instrumental in shaping walking activity are used to develop a systematic analysis of pedestrian travel. The methodology provides a generalized supply-demand conceptualization of the problem based on pedestrian needs and accommodations (or impedances) and derives a strategy to show that the frequency of walking trips is related to the quality of the walking environment. Trip characteristics define the needs of various socioeconomic pedestrian types. The influential elements of the walking system are stated in terms of accommodations, such as overpasses, pedestrian tunnels, or lighting along walkways, and of impedances arising from high traffic volumes or the barriers posed by the roadways themselves. Trade-off effects between these two major factors establish an index of the quality of the walking environment. Procedures for gathering field data to quantify pedestrian needs and accommodations are proposed, and graphical means of using the information to measure the impact of transportation projects on pedestrian mobility are illustrated. Specific data sought are attitudinal survey information on walking incentives and quantitative measurements of walking accommodations. It is envisioned that the systematic procedures proposed can be incorporated into the highway planning process to improve pedestrian conditions.

•IN recent years, pedestrian travel has received relatively little attention from planners. Although modern engineering has provided technically efficient highways and is in the process of creating advanced ground rapid transit and innovative air travel systems, the means of anticipating and accommodating pedestrian needs remain primarily an art (1). Major transportation studies have, as a rule, treated pedestrian travel in a secondary fashion as an element of vehicular trips, since walking trips have not been goal-related (2). These transportation analyses have served the purposes for which they were intended, but today an awareness of the many indirect impacts of transportation projects requires that planners anticipate certain environmental consequences in order to check ill effects. Accordingly, the achievement of broader social objectives demands that measures be taken to lessen the impact of new roadways on the local activity that sustains residential and business neighborhoods.

THE CASE FOR PEDESTRIAN TRAVEL

A major component of the neighborhood system that must be acknowledged consists of the forces acting on those people who, because of their geographic location, age, economic status, or physical condition, must rely on walking as a primary means of mobility. In most instances, the benefits of a new or improved transportation system do not really apply to these groups. It is also quite common that vehicular way facilities may become walking impedances to the same people they are cited to benefit (3, 4). Such a situation propagates short auto trips as substitutes for journeys previously accomplished on foot. Although this facet is appreciated by highway engineers and urban

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planners, little information is available with which to measure local transportation requirements.

A synthesis of the total transportation picture to include the needs of the dependent pedestrian as well as to encourage the volunteer walker requires a knowledge of pedestrian attitudes and habits. In order to examine these aspects, it is necessary to recognize and measure factors in the physical environment that influence people to walk or not to walk for various purposes. Consider the neighborhood environment of the urban poor, which creates the risk of assault, rape, theft, and harassment by criminal elements. Here lighting, good sight distances, maximum exposure, and security devices may constitute significant travel aids (5). Also, the aged, the very young, and the handicapped require special attention in the design of curbs, stairs, ramps, handrails, etc. In these cases the evaluations of existing pedestrian facilities, particularly newer ones, can be an important source for new planning and design data (6). This conclusion appears valid since measurements on the psychological and physical dimensions of the walking system components, along with the influences of larger structures such as tunnels and bridges, may reveal new or improved criteria. Finally, the frequency of travel on pedestrian overpasses, walking volumes, and walking patterns must be examined to determine the benefits of implementing pedestrian travel aids.

In parallel with the effects of pedestrian accommodations on walking, the barriers to non-vehicular travel created by new highway facilities must be ascertained in order to establish the types of facilities required to nullify constraints on walking. For example, the separation of the residential and commercial components of a neighborhood by a highway may cause significant hardships on those without access to an automobile.

OBJECTIVES

The following major areas are selected for structuring the goals of a systematic analysis of pedestrian travel:

1. The special needs of pedestrian groups who must rely primarily on walking as a means of transportation;
2. The impact of newly constructed transportation works on pedestrian travel patterns and on living habits;
3. The degree of success of existing pedestrian facilities; and
4. The attitudes, including a hierarchical ranking, of various socioeconomic pedestrian types with regard to their walking accommodations.

These goals can be further synthesized to state a set of elements that underlie any pedestrian situation:

1. Pedestrian needs—These needs are the reasons or demands for walking that are associated with pedestrian subgroups. The major objective here is the quantification of pedestrian demands.
2. Pedestrian accommodations—Accommodations are herein designated as conveniences (or impedances) to walking. These factors represent the supply counterpart to the demand described in 1 above.

The aforementioned factors are now taken to provide the core elements in the design of a methodological framework for analyzing the pedestrian transportation problem.

METHODOLOGY

General Development

Many fundamental concepts, theories, and models that have been applied to the analysis of vehicular travel can be utilized to develop a framework for studying pedestrian activity. In any given environment, pedestrian needs and movements are hypothetically related in various degrees to certain trip-maker characteristics, trip factors, and the elements of the walking environment (somewhat analogous to the use of transportation system characteristics in conventional urban transportation planning). The following is a tentative listing of the typical dimensions that provide a basis for monitoring and analyzing pedestrian movements:

Functional Classification

1. Local (all walking)
2. Interzonal or multimodal (of which the walking portion is considered a separate mode)
   a. At trip origin
   b. At trip destination
   c. At vehicular transfer points

Trip-Maker Characteristics

1. Age
2. Auto ownership (individual or household level)
3. Family size
4. Handicap level
5. Income level
6. Sex
7. Type of neighborhood
8. Location of residence relative to CBD

Trip Characteristics

1. Trip purpose
   a. Work
   b. Shopping
   c. Visit friends
   d. Recreation
   e. Personal business
   f. Religious
2. Time
   a. Season
   b. Day of week
   c. Time of day
3. Trip length
   a. Distance
   b. Time in transit

Walking System

1. Obstructions or barriers to pedestrian movements created by freeways and other high-volume roads (impedances)
2. Structures, signals, laws, etc. to accommodate pedestrian movements and/or alleviate pedestrian-vehicle conflicts (accommodations)

The functional classification listed above examines the walking trip in two specific contexts: the local trip (typically in an individual's residential environment) and as the component of a vehicular trip. The latter type of pedestrian movement defines the walk to a residential collector vehicle and the journey from a terminal (parking lot, bus station, etc.) in a major activity center, particularly the CBD.

These dimensions are now implemented to establish the nature of the demand for walking trips, the impedances on such movements by highways, and the effects of providing accommodations that make more opportunities accessible via walking. The demand for walking travel is postulated to derive as follows:

$$D_w = F(FC, TM, TC, WS) \quad (1)$$

where

D_w = a measure of individual walking demand (number of trips per unit time, probability of walking, etc.) for conditions FC, TM, TC, WS;
FC = the functional class of the trip;
TM = the characteristics of the trip-maker;
TC = the trip characteristics; and
WS = an index of the quality of the walking environment.

Equation 1 provides a mechanism for conceptualizing the various interrelationships that describe the pedestrian problem.

The Walking Environment

The facility for quantifying the impacts of highways and pedestrian accommodations on the walking behavior of the different travel classes (TM, TC) is based on the following hypothesis: Highways have negative impacts on the walking environment while pedestrian accommodations enhance the potential for walking travel.

Hence, the quality of the walking environment is derived from a net figure that accounts for the positive factors (accommodations) and negative factors (impedances):

$$WS = F\left(HY^-, AC^+\right) \qquad (2)$$

where

WS = index of the quality of the walking environment;
HY^- = the impedances caused by highways; and
AC^+ = the pedestrian accommodations provided.

Equation 2 provides a basis for an index that can be used to compare the quality of different walking environments and/or to monitor the changes that take place over a period of time in a particular pedestrian system.

Now a method for specifying how the walking environment enhances or prohibits interactions between individual and urban opportunities is introduced:

$$d_{avg} = \sum_{w=1}^{N} \frac{D_w}{N} = \sum_{w=1}^{N} F_w(FC, TM, TC, WS) \qquad (3)$$

where

d_{avg} = the average number of walking trips or average number of person walking-miles for a given category of the explanatory variables that is observed in a given environment;
D_w = walking demand for a specific category; and
N = total number of categories.

Equation 3 gives the average walking activity observed in a given urban area (e.g., person-miles of walking per day). If the socioeconomic dimensions (TC, TM) and areal characteristics (FC) are held constant, Eq. 3 becomes

$$d_{avg} = F(WS) = F\left(HY^-, AC^+\right) \qquad (4)$$

Thus, individual walking activity is directly related to the quality of the walking environment.

The preceding functional development, which establishes important relationships and dimensions of pedestrian travel, is now employed to establish an experimental design for conducting a diagnostic analysis of pedestrian activity. It is premature at this time to develop forecasting tools for pedestrian analysis at the stated level of detail since the state of the art is relatively primitive compared with that for vehicular travel. It is thus appropriate that initial walking analysis, as suggested in the next section, be concerned with describing behavior in order to propose meaningful hypotheses on the subject.

EXPERIMENTAL DESIGN

Analysis of Pedestrian Needs and Accommodations

In order to correlate the findings concerning needs and accommodations, pedestrians are classified according to their environmental-socioeconomic status. Individual attitudes toward walking needs and accommodations are hypothesized to be similar within certain groups (6). Age, sex, and income are typical factors for group identification but further subclassification may be necessary or desirable. Once pedestrian categories have been determined, trip-makers in the data sample are assigned to a category and then characterized by the following attributes:

1. The total number of trips made from their domiciles per week;
2. The number of walking trips they make per week in each of several walking purpose (need) categories such as family shopping, personal business, employment commuting, recreation, etc.; and
3. Their attitudes with regard to accommodations for walking such as safety, comfort, convenience, and aesthetic considerations.

The need analysis proceeds with a comparative study that utilizes the following input data:

p_{ij} = number of type i need walking trips observed for pedestrians in group type j;
P_j = total number of walking trips observed for pedestrian in group j;
t_{ij} = total number of type i need trips observed for pedestrian in group type j;
T_j = total trips of pedestrians in group type j;
m = number of different type trips;
n = number of pedestrian type groups;
α_{ij} = percentage of walking type trips i, relative to the total walking trips made by group j; and
γ_j = percentage of total walking trips for group j relative to the total trips made by group j.

Thus,

$$P_j = \sum_{i=1}^{m} p_{ij}$$

$$T_j = \sum_{i=1}^{m} t_{ij}$$

$$\alpha_{ij} = 100\ p_{ij}/P_j$$

$$\gamma_j = 100\ P_j/T_j$$

The summary results of this interpretation are shown in a walking need versus pedestrian type index matrix in Figure 1.

In a similar fashion, an accommodation index matrix can be derived for various pedestrian groups. Relative weights for accommodations that facilitate and encourage walking, as perceived by the different pedestrian groups, are determined from attitudinal surveys. The output of this analysis is then a series of normalized weights, β_{ij}, which indicate the perceived importance of accommodation i to pedestrian group j.

The format for this data interpretation is shown in Figure 2. This chart indicates physically desirable aspects according to orders of importance and can be employed to provide a set of indicators for any particular neighborhood or areal situation.

Figure 1. Pedestrian needs versus type index matrix.

		PEDESTRIAN TYPES				
		1	2		j		n
		Urban Handicapped	Urban Housewife		Type j		Suburban Businessman
Needs	1. Shopping	23	38		:		12
	2. Personal Services	16	21		:		27
	3. Business Commuting	2	6		:		53
	4. Visitations	8	11		:		3
					:		:
	i Activity i	. .	. .		α_{ij}		α_{in}
							:
	m Recreation				α_{mj}		α_{mn}
	TOTALS (%)	100	100		$\Sigma\alpha_{ij}$		100
	Walking Trips ÷ Total Trips (%)	93	86		γ_{ij}		14

Figure 2. Pedestrian accommodation versus group index matrix.

		PEDESTRIAN TYPES					
		1	2		j		n
		Urban Handicapped	Urban Housewife		Type j		Suburban Businessman
Accommodations	1. Crosswalk Controls	25	36		:		21
	2. Street Lighting	8	48		:		8
	3. Ramps and Railings	57	16		:		2
	4. Color and Cleanliness	5	12		:		63
	: :				:		:
	: :				:		:
	i Activity i	. .	. .	. .	β_{ij}	. .	β_{in}
	p Visibility				β_{mj}		β_{mn}
TOTAL (%)		100	100		$\Sigma\beta_{ij}$		100

Analysis of Impact of Highways on Pedestrian Mobility

By utilizing data from neighborhood environments that have been impacted by a transportation project, comparisons can be made with similar neighborhoods that have not been so affected. The index for such comparisons might be average person walking-miles per unit time for different trip-makers and/or different trip types. These statistics could then be used to derive a relationship between walking behavior and the amount, or lack, of certain physical accommodations that affect foot travel. This information, therefore, provides a means of measuring the impact of highway development on continued pedestrian accessibility to former facilities or activities.

This analysis can be taken at either of two levels; the first is indicative of inter-area comparisons, while the latter represents a more detailed diagnosis of a local problem. The former method simply takes a statistic of the observed areal travel (d_{avg}) and plots it versus the related walking environment quality index. A hypothetical example of this approach is shown in Figure 3, where k designates different study areas. For example, if the trip-maker and trip characteristics are held constant, inter-area comparisons will relate the change in walking behavior ($\Delta N_{1,\ 1-2}$) caused by the difference in quality of the walking environment ($\Delta WS = WS_2 - WS_1$). Also, this model can be employed to specify changes between the walking behavior of different groups or different trip types in a given area. Here, the walking quality remains constant (e.g., WS_1) and a particular TM or TC dimension is varied [e.g., $(TM, TC)_1$ to $(TM, TC)_j$]; $\Delta N_{1-j,1}$ is then a measure of the different travel habits within a certain area.

Similar information that derives from before-and-after study in a single area can alternatively be examined in a more detailed fashion. Here the cross-sensitivity between pedestrian travel strata is represented in view of changes in a single walking environment. For example, Figure 4 shows the before-and-after behavior of typical groups resulting from a highway project. Thus, the difference between the a and b level represents the travel demand that the provision of pedestrian accommodations must induce in order to alleviate the disturbances to foot travel created by highway development.

Data Requirements and Acquisitions

The attainment of the basic goals pertaining to pedestrian analysis depends, to a large extent, on the quality of the acquired data. It is imperative that information be obtained from similar type individuals in differing environmental circumstances as well as from different pedestrian types in the same environment.

A broad data base is necessary in order to gain knowledge on pedestrian behavior. The perceived data sources consist of the following:

1. Attitudinal travel information from individual and group interviews;
2. Existing data on walking behavior in different environments; and
3. Field evaluations of walking environments.

In the first case, information is required in order to determine how individuals perceive the role of walking in their life-style, their perceptions of the various elements that compose the pedestrian system, and their walking and travel habits. The primary mode for soliciting judgment data is an attitudinal questionnaire designed to determine the most critical factors underlying a stated decision and the relative weights the individual associates with each measure.

In this case, certain samples of individuals should be selected from different walking environments and asked to meet as a study group at a local public building. The meeting is designed to subject the sample group to the following tasks:

1. Fill out an information form citing pertinent socioeconomic and travel data.
2. Participate in an attitudinal survey to provide judgments on the following: (a) perceived deterrents to walking, (b) walking travel needs, and (c) hypothetical situations clearly presented via visual aids.
3. Fill out a checklist for all trips taken during a specified time period.

Figure 3. Inter-area comparison of walking.

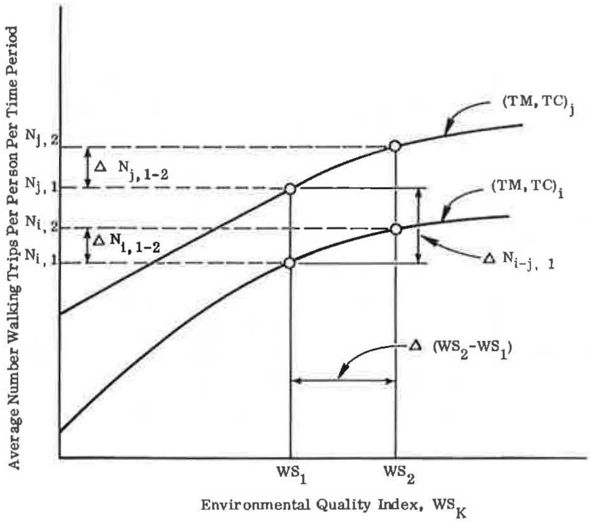


Figure 4. Local analysis of changes in walking activity.

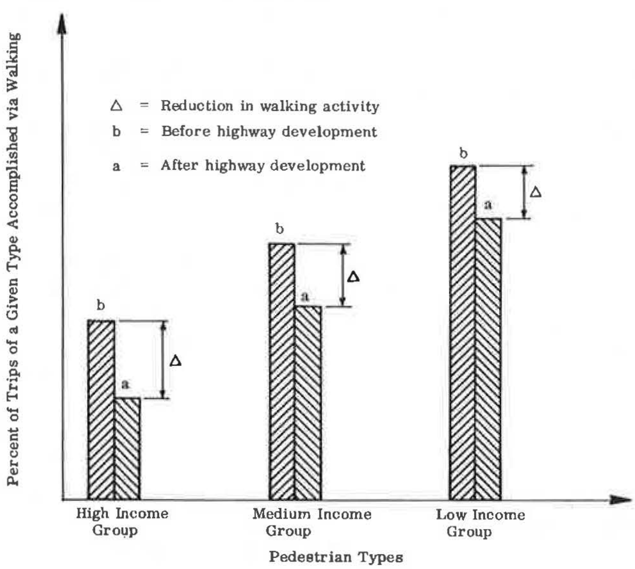
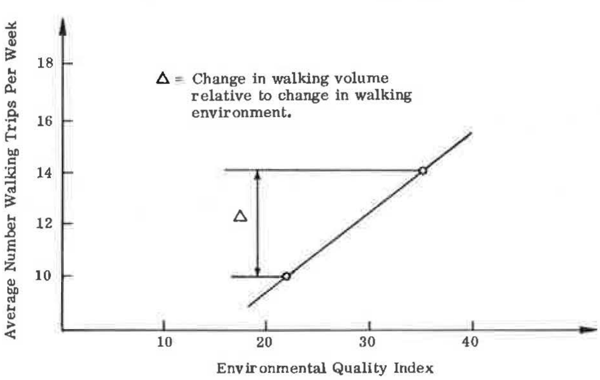


Figure 5. Example environmental-walking impact analysis.



Of particular significance is the checklist to be filled out for each trip taken by the individuals in the sample group. This checklist is proposed to strengthen the diary approach to obtaining longitudinal travel data. This method will guarantee consistency between the responses of various individuals, which becomes a problem when comparing the information in diaries. Also, besides being more objective than diary notes, the checklist data can be processed more efficiently.

The second type of data derives from existing sources to provide rapid data on pedestrian activity (i.e., origin-destination surveys, parking studies, etc.). This information would supplement in-house travel data.

The final information required concerns the selection and measurement of elements of the walking environment that accommodate or constrain pedestrian activity. Surveys must be made in order to define those factors that determine the quality of the walking environment. Once these elements are determined, the appropriate engineering measurements can be made along typical walking routes in any study area. The measures anticipated here include the type of quantifications of pedestrian facilities outlined in the Traffic Engineering Handbook (7).

IMPLEMENTATION OF STUDY METHODOLOGY

The program described is quite broad and is intended to apply to any specific walking travel analysis. However, two primary subsets of walking population are inferred to be of particular interest here, namely (a) those who are most dependent on walking for mobility and (b) those vehicle trips in suburban or other residential areas whose needs could be met by walking if satisfactory accommodations for pedestrian trips were provided.

For example, initial study will concentrate on only those socioeconomic classes and districts that exhibit the above circumstances. In the first case, the travel behavior of low-income groups (high probability of no automobile being available) and the aged and handicapped (unable to drive) is examined. For the latter problem, the inhabitants of residential communities that are spatially close to such trip attractions as shopping centers and recreational areas but face physical barriers that discourage walking, such as freeways, are considered.

Although the scope of the total walking population has been reduced, it is assumed that any changes in the walking environment that will enhance or deter the pedestrian movement of the stated subpopulations will have similar impact on total walking travel, although possibly in varying magnitudes for different socioeconomic classes (6). It is also noted that the scope of analysis required of the physical walking environment is not reduced by limiting the type of trip-makers studied.

Example

A hypothetical example of the application of the methodology discussed in this paper and summarized in Figures 1, 2, and 3 is given to illustrate the procedure. Assuming that the appropriate data (as described earlier) are available, the processed results give the pedestrian need versus type matrix for two areas and provide the following summary statistics:

Area 1—Average number of shopping (TC) trips per week for low-income individuals (TM) accomplished by walking was 10.
Area 2—Similar statistic is 14.

The respective accommodation versus type index matrices give

Area 1 index = 22
Area 2 index = 35

Figure 3 is next used to analyze the impact of the walking environment on these two identical socioeconomic and trip categories. This is shown in Figure 5, where a linear relation is given for the trade-off between walking and pedestrian environment.

The preceding example is quite elementary, but nevertheless the practical application in the planning for pedestrians is indicated.

SUMMARY

This paper presents a comprehensive framework to guide study and analysis of pedestrian needs and accommodations. The development derives from current transportation planning principles, which are utilized to synthesize the various components of a pedestrian-environmental system. It is envisioned that these systematic procedures can immediately be incorporated into the highway planning process.

The format has been designed to show variations in walking behavior among different trip types and travel groups in different walking environments such that the results can be used to guide policy decisions in any urban area. The anticipated findings can serve as preliminary guidelines for assessing pedestrian needs and may provide the necessary hypotheses to develop more refined techniques in forecasting changes in pedestrian behavior when walking environments are altered.

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