1982

Spatial Structure and Decision-Making Aspects of Pedestrian Route Selection through an Urban Environment

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SPATIAL STRUCTURE AND DECISION-MAKING
ASPECTS OF PEDESTRIAN ROUTE SELECTION THROUGH
AN URBAN ENVIRONMENT

by

Michael R. Hill

A DISSERTATION
Presented to the Faculty of
The Graduate College in the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy

Major: Geography

Under the Supervision of Professor Robert H. Stoddard

Lincoln, Nebraska
December, 1982
TITLE

SPATIAL STRUCTURE AND DECISION-MAKING ASPECTS OF PEDESTRIAN

ROUTE SELECTION THROUGH AN URBAN ENVIRONMENT

BY

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October 4, 1982

October 4, 1982

October 4, 1982

October 4, 1982

October 4, 1982

SUPERVISORY COMMITTEE

GRADUATE COLLEGE

UNIVERSITY OF NEBRASKA
The review of literature is hierarchically organized in terms of the pedestrian's ever widening spatial skills: walking, crossing streets, and choosing routes. Route choice is conceptualized as a game played upon an urban street system viewed as a graph. Completing a walk requires the sequential selection of edges from those available in the graph. Each sequence of choices is called a strategy. This study is an investigation of the characteristics of strategies employed by pedestrians in their selection of routes from one place to another.

Data were collected in Lincoln, Nebraska. Two hundred pedestrians were intercepted, tracked to their destinations, and handed mail-in questionnaires which asked each subject to describe the route of the walking trip just completed. Eighty-three subjects (86% of those who returned questionnaires) responded with accurate descriptions of the tracked portions of their trips. One hundred additional pedestrians were intercepted and asked for directions to the nearest elementary school. Finally, fifty elementary school children were also
individually tracked on their way home from school.

Data analysis employed the following classifications and measures. Classifications for trip networks and trip types were developed. Standardized measures of spatial structure (simple-complex dimension) and route choice (freedom-determinancy dimension) were also devised. Both measures are adaptations of the formula for standardized scores (Z-scores).

The following hypotheses were empirically corroborated:

1. pedestrians nearly always choose distance-minimizing routes,
2. young pedestrians select relatively more complex routes than adults,
3. a stranger who asks for directions generally receives structurally simple routes, and
4. adult pedestrians exhibit more complexity in their own walking routes compared to the complexity of routes given to a stranger asking for directions.

It was also hypothesized (5) that women select less complex routes than men. The exact opposite was discovered. Women are experienced, knowledgeable pedestrians who often complete longer trips than men.

Whether a "strategy" framework is experientially relevant to pedestrians remains an open question for future research.
DEDICATION

This work is dedicated to my late uncle, Dr. Eugene Hilligoss, Professor of Cello and Chair of the String Department, School of Music, University of Colorado, who eventually taught me that most things academic are much more understandable if one fosters a sense of humor.
ACKNOWLEDGEMENTS

Many friends and colleagues have encouraged and supported this work at various times and in different ways. I owe all of them a deep debt of gratitude.

Acknowledgement for financial assistance is due the U.S. Department of Housing and Urban Development for providing a Doctoral Dissertation Grant in support of the data-collecting phase of this project.

For her patience and accuracy during the key-punching of the data for this study, I wish to commend June Bissell.

The final stages of writing and analysis would not have been possible without the special understanding and strength of my partner, Mary Jo Deegan.

Most central to this study, I thank the pedestrians of Lincoln.
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CHAPTER ONE

THEORY

Introduction

The primary objective of this study is the development, extension, and review of a framework within which to discuss the spatial structures and decision-making strategies found in human way-finding in urban areas. In order to give empirical grounding to this exercise, the routes selected by urban pedestrians as they walk from one place to another are given central attention.

Despite the ubiquity of the automobile, it is the pedestrian mode which holds the key to transportation problems in urban areas of the United States and many other countries. The centrality of the pedestrian mode was put succinctly by a participant in the 1981 Transportation Research Board's Summer Workshop on Pedestrians who said: "The pedestrian is the glue of the entire transportation system; it is the pedestrian mode which ties it all together." Walking is a basic,
fundamental, pre-technological transportation mode. It is the original mass transit. Thus, this discussion of human way-finding in urban areas is intimately bound up in the peculiarities and characteristics of travel in the pedestrian mode. A comprehensive review of relevant literature concerning the social/behavioral aspects of the pedestrian mode in general and pedestrian route choice in particular is therefore attempted in the sections which follow. First, however, a short section noting the precedents for a geographical study of pedestrian route selection in urban areas is provided to help set the present research project within the disciplinary matrix of contemporary geography.

Geographers and the study of pedestrians

It should be noted that the present study is by no means the first geographical consideration of pedestrians and their behavior. Gantvoort (1971:454) observed: "It seems that originally [the pedestrian] was of interest only to social and economic geographers." He further asserted that:

One of the first European investigators of pedestrian traffic must certainly have been Hubschmann, whose study of a shopping street in Frankfurt, Western Germany, was published in 1952. (p. 454).

This early work found an intricate relationship between urban land values and the volume of pedestrian flows.

Interest in pedestrian flow in central business district areas
remains characteristic of several of the more recent studies completed by geographers during the past twenty years. Brenda Thompson and P. Hart (1968) marshalled 80 of their geography students into the field to conduct a cordon count and questionnaire study of visitors to the town center of Chichester, United Kingdom. Direct observation of pedestrians in central business districts is also recommended by Donald Deskins, Jr. and John D. Nystuen (1973) as:

... a good way to introduce geographical ideas to students who wish to experience a closer link between their studies and real world problems. (p. 105).

Interestingly, Deskins and Nystuen's proposal was conducted as a field exercise in Atlanta, Georgia, in 1971 during a leadership conference of the Association of American Geographers' Commission on Geography and Afro-America (p. 126).

Writing in the East Midland Geographer, G.J. Lewis (1974) reported on pedestrian flows in central Leicester, United Kingdom, as a "study in spatial behaviour" (p. 79). Others have attempted to model flows of pedestrians in central business districts. One such effort is reported by the team of Janne Sandahl and Martin Percivall (1972). Both authors were listed as planners at the time their article appeared, but the biographical notes preceding their paper indicate that Percivall "graduated from Merton College, Oxford in 1962 with a major in geography" (p. 359). Sandahl and Percivall explored the potential utility of producing regression models of pedestrian flows in town
centers. Emphasis on application to urban planning problems is a central focus in Marchand's (1974) study of pedestrians' perceptions of the urban environment. At the time Marchand published his observations on the routes Parisians select when walking to a Metro station, he was associated with the Department of Geography at Northwestern University. Review of the available literature concerned with pedestrians reveals many publications which have an applied, urban planning focus. It may well be that several of these papers have been authored by researchers who have earned degrees in geography before becoming primarily identified as professional planners.

Other geographical studies have moved beyond a narrow concern with pedestrian flow per se. Brian Goodey (1974, 1975) has provided an excellent review of the principles for designing town trails and urban walks. Taking quite another turn, Clarke Schneider (1975) assumed walking as a transport mode in his highly theoretical models of space-searching behavior reported in *Geographical Analysis*. Most radical in its import for both the philosophy and methodology of behavioral geography is David Seamon's (1979) monograph on human movement in the phenomenological construct of the "lifeworld". The members of Seamon's "environmental experience group" at Clark University reported on the phenomenology of many pedestrian experiences. The results were published in Croom Helm's series in Geography and Environment. Associated with the Department of Geography at Clark at the time the manuscript was completed, Seamon moved on to a position in geography at York College of Pennsylvania. These works, together with
Marchand's, noted above, demonstrate a broadly-framed concern with the environment and the spatial behavior of the pedestrian.

Finally, two doctoral dissertations in geography have addressed the spatial aspects of walking. Thomas Underwood's (1975) work at the University of Western Ontario focused on the preferences of younger pedestrians. Specifically, he studied children's preferences for city streets as travel routes. A more traditional concern for pedestrians in central business areas is reflected in Sheldon Blivice's (1974) questionnaire research on routes pedestrians take when walking to work in Munich, West Germany. It is interesting to note that Nystuen, referenced above, served as the chair of Blivice's supervisory committee at the University of Michigan. Thus, it is with a certain degree of geographical precedent that the present study is focused on the spatial aspects of route selection by pedestrians in urban areas.

Why study pedestrians?

Observing that pedestrians have been studied by geographers does not fully satisfy the inquiry which asks why should they be studied at all. There are several reasons which argue in favor of focusing on the apparently "simple" behavior of the pedestrian. First, the deceptive simplicity of the pedestrian experience provides an excellent empirical focus for examination of a wide range of topics prominent in recent work in behavioral geography. Empirical studies and conceptual work regarding territoriality, crowding, privacy, personal space,
sensory overload and deprivation, approach-avoidance, navigation and orientation, mental mapping, search process, and environmental perception, evaluation, and decision-making all bear on various facets of the pedestrian experience. Empirical verification of the viability of these conceptual ideas presents a lacuna which the study of the pedestrian helps to close. The inner processes and complexity of pedestrian behavior are far greater than the outward simplicity suggested by the geometrical representation of a pedestrian trip as a line connecting an origin and a destination. The complexity which lies behind this apparent simplicity provides a major challenge to students of behavioral geography.

The applied geographer may well question the utility of the growing list of behavioral concepts and constructs if they cannot be integrated in an empirically verifiable way to understand the essence of an everyday, ordinary behavior such as walking. For example, of what use is it to know that individual differences in "mental maps" can be recovered unless it can be demonstrated that these hypothesized cognitive representations of the environment have behavioral significance for a fundamental and common activity such as walking from one part of a city to another. Without an effort directed at conceptual integration and empirical verification and interpretation at this basic level, the individual pedestrian remains before the eyes of the behavioral geographer as an enigma. In short, the pedestrian serves as a handy foil for at least a few researchers who are attempting to demonstrate the relevance of concepts now evolving in behavioral
Two other factors combine with the possibility of conceptual integration to recommend the pedestrian experience for a higher priority in behavioral geography than it presently enjoys. First is a highly practical point which is so obvious that it may require emphasis. It is, simply, that pedestrians are readily available for observation and study in a wide variety of environments ranging from crowded urban streets to the solitude of wilderness hiking trails. The very ubiquity of pedestrians presents researchers with a wonderful opportunity to observe a cross-section of normal individuals engaged in normal routines in everyday, normally experienced environments. Normality is underscored because focusing on the ordinary pedestrian frees the researcher from the limitations of studies such as those based on college freshmen who have been coerced into participating in an experiment or on institutional settings with little generalizability such as mental hospitals and remote military installations. The great variety of pedestrian environments and the potential heterogeneity of the pedestrians themselves are methodologically problematic, but this situation goes a long way in improving the external validity of the researcher's empirical findings. While the control possible in an experimental setting is lost when observations are made in the undisturbed, natural environment, it is this everyday, ordinary environment to which the behavioral geographer ultimately wishes to be relevant. This argument is not offered to denigrate the insightful research suggestions which have sometimes issued from laboratory research, but
to merely emphasize that to be useful, the concepts of behavioral geography must be interpretable in everyday settings. What is truly fortunate is that a large selection of concepts (many of them developed in experimental labs) is available with which to work and conceptualize. Study of the naturally occurring, ubiquitous pedestrian undoubtedly requires future refinement and further development of many of the ideas and techniques currently under discussion by behavioral geographers. But, researchers who pursue the behavior of the pedestrian as an object of study will find a large and growing number of studies on which to draw for inspiration (see, for example, bibliographies on pedestrians in Garbrecht, 1971a; Bartholomaeus, 1972; Akoi, 1977/78; Elkington, McGlyn, and Roberts, 1976; Hill, 1976; Flynn, 1977; and Hill, 1982).

From an applied point of view, **pedestrianization** is now a basic concept in urban design (see, for example, Lewis, 1966; Fruin, 1971; Greater London Council, 1973; Brambilla and Longo, 1977; Pushkarev and Zupan, 1975; Breines and Dean, 1974; and Garbrecht, 1978, 1981). Any usable conceptual integration of behavioral geography's concepts relating to the pedestrian experience has ready application in the field of planning and urban design. So far, the urban designer's efforts in formulating an imaginative spatial imagery with which to create and plan pedestrian-oriented projects (e.g., Thiel, 1961, 1970; Noe and Abernathy, 1966; Halprin, 1965; Simonds, 1974; Foster, 1974; and Mitropoulos, 1973, 1975) have not been matched by environmental scientists such as behavioral geographers. To date, students of
human-environment relations have yet to develop an holistic, empirically grounded understanding of the pedestrian's relationship to the environment. Rightly or wrongly, urban designers and planners expect such understanding to be forthcoming from the human-environment research community of which behavioral geography is a member.

In sum, this introduction has provided three reasons why behavioral geographers might continue to study the pedestrian. First, the behavior of the pedestrian appears relatively "simple" and should be explainable if, in fact, behavioral science is capable of demonstrating empirical viability for its developing conceptual frameworks. Second, pedestrians allow the study of normal people in everyday environment. Third, pedestrianization schemes are gaining applied acceptance among urban planners and urban designers. Virtually any insight relevant to the planning and design of such projects will find a ready and willing audience. It has been noted above, however, that the experience of the pedestrian is only superficially "simple". In the sections which follow, the reader is introduced to a survey of insights into the character of the pedestrian's world as revealed in human-environment research of (for the most part) the last decade.

Walking, Crossing Streets, and an Introduction to
Choosing Routes

The principal empirical and theoretical focus of this study concerns the routes that pedestrians select to get from point A to point B. In a spatial sense, route selection is the pedestrian's most
sophisticated achievement. It builds upon the more fundamental skill of walking *per se* and, if the pedestrian walks any distance at all, the risk assessment skills required in crossing streets traversed by all too frequently lethal automobiles. In the following sections, the reader is introduced to these related but hierarchical spatial skills.

**Walking**

The act of walking is rarely considered as a mode of transport *per se*. Rather, walking is usually studied as an adjunct of mechanized facilities such as automobiles and rapid transit. There are, therefore, numerous studies of "acceptable walking distances", i.e., investigations of how far people are presumably willing to walk in order to catch a bus or park a car. The summary by Bandi and others (1974) provides a good example of this work. It is indeed rare to find attention given to walking as a mode-in-itself and this review must draw upon research which has usually tied the pedestrian to motorized vehicles.

Walking requires many techniques and practices which are not generally brought under conscious reflection. Ryave and Schenkein (1974) note:

> It is after all, these methodic practices that make the phenomenon of doing walking so utterly unnote-worthy at first glance to both lay and professional social analysts alike; indeed, it is through these methodic practices that the commonplace presents itself to us as ordinary, and the exotic as the extraordinary. (p. 265).
The reader is now invited to explore several facets of this ordinary practice, to bring walking into reflective consciousness. First, consider the speeds at which pedestrians travel.

**Velocity Studies**

It would fill many pages to recount the many findings concerning pedestrian velocity. Early studies include Hoel (1968), Navin and Wheeler (1969), and Older (1968). An especially comprehensive compendium is Fruin (1971). The most conscientious attempt to integrate information of velocity in an applied urban planning framework is Pushkarev and Zupan's (1975) landmark report on *Urban Space for Pedestrians*. The behaviorally interesting aspects of the velocity studies can be briefly summarized as follows. The general findings are (1) that men walk faster than women, (2) that youths generally walk faster than older people, and (3) that pedestrians in groups tend to walk more slowly than unaccompanied pedestrians. These findings, or some slight variation on them, find frequent and consistent re-validation. For example, Boles and Hayward (1978) recently reported that females "walked significantly more slowly than males under all environmental conditions" (p. 33).

One of the more interesting velocity studies in recent years looked at velocities within large, seemingly cohesive groups, such as crowds exiting *en masse* from large buildings. Henderson and Lyons (1972) observed 2000 people in the walking mode and found that males, even under conditions of extreme crowding, still walked faster than
females in the same crowd. There may, however, be problems in taking these and other velocity studies at full face value.

Gifford and colleagues (1977) identified a major flaw in the majority of the reported velocity studies:

Unfortunately, these studies have not typically investigated more than one variable at a time, compared the influence of variables or assessed their interactions. Nor have the effects of walking in groups or under different weather conditions received much attention. (p. 66).

They conclude by warning planners to be aware of the rather large variations in individual pacing and the relative effects of significant variables on overall rates. Thus, rather than closing the door on a long series of studies, Gifford and colleagues have opened the way for careful re-analysis of many engineering-oriented velocity studies.

*Walking and the Climatic Environment*

It has been assumed by many designers that environmental variables under the control of engineers might well be adjusted to provide "optimum" walking conditions for pedestrians. This assumption runs into difficulties in outdoor settings where the engineer has little control over the environment. Arens and Ballanti (1975), who conducted a review of attempts to understand the effects of wind on pedestrians concluded that many wind models would probably give poor estimates of human comfort in outdoor pedestrian areas. Cohen and others (1977) concentrated on the effects of wind on pedestrians and
considerable mathematical modelling and wind-tunnel testing was completed. In moving from abstract models to observations of actual pedestrians walking under various windy conditions, Cohen and his colleagues demonstrated that empirical study can often result in generating more questions than answers (Hill, 1978b). They point in the direction of correlating behavioral observations with models of new construction in wind tunnels (with the aim of eliminating extreme cases of wind shear prior to construction), but there are several technical and methodological problems to be worked out before this technique will become readily useful and available. To date, researchers have looked primarily at wind while doing much less with sunlight, temperature, precipitation, and other climatic elements.

The Physiology of Walking

Walking against the wind, through a snow storm, or up a steep hill consumes human energy. How much energy is a question posed by researchers in physiology and bio-mechanics. A good example of the field of questions available in this area is found in Dean's (1965) research on energy expenditures in level and grade walking. The large literature on metabolic rates, energy consumption, heart rates, etc., quickly jumps the reader into the realms of sports medicine, physiology, and related medical researches. Although this literature is interesting in its own right, it is beyond the scope of this presentation to cover it in detail.


**Pedestrians as Vehicular Units**

An especially important conceptualization of the pedestrian is presented by Erving Goffman (1971) in his book: *Relations in Public: Microstudies of the Public Order*. In this frequently cited work, Goffman observed that vehicular units are distinguished, in part, by the thickness of their outer shells or skins. He continued:

> Viewed in this perspective, the individual himself, moving across roads and down streets--the individual as pedestrian--can be considered a pilot encased in a soft and exposing shell, namely his clothes and skin. (p. 7).

In this conceptualization, the ordinary pedestrian is seen as a pilot who navigates a vehicle with some surprising characteristics.

The pedestrian vehicle is amazingly vulnerable to injury from the mechanized vehicles with which it is often forced to share the road. At the same time, it also possesses some attractive characteristics. Goffman continued:

> Pedestrians can twist, duck, bend and turn sharply, and therefore, unlike motorists, can safely count on being able to extricate themselves in the last few milliseconds before impending impact. Should pedestrians collide, damage is not likely to be significant, whereas between motorists collision is unlikely (given current costs of repair) to be insignificant. (p. 8).

This flexibility is rarely reflected upon. Pedestrians, unlike motorists, can stop quickly to look at something that interests them (Rapoport, 1977). They can reverse themselves, walk through buildings,
climb over barriers, and negotiate tight passages with a facility impossible for automobiles.

Goffman's (1971) work is particularly concerned with the social nature of pedestrian vehicle navigation, but he began by noting that the pedestrian must also take account of the physical environment, especially the sidewalk. This environment is observed through a process called "scanning" which Goffman described in the following way:

I have so far considered only those pedestrian traffic practices that are interpersonal (or rather intervehicular) in character. There are, of course, single unit practices. For example, as the individual proceeds along his course, he scans the flooring immediately in front of him so that he will have time to sidestep small obstructions and sources of contamination. Here, too, is a structured scanning that is performed without much awareness. Within the oval scanned for oncomers, then, is a smaller region that is also kept under eye. (p. 16).

The process of scanning the environment for oncoming traffic is examined below in more detail. What is important here is to note that the pedestrian, even when alone, is performing a sophisticated, but autonomic, scanning of the physical dimensions of the environment.

Golson and Dabbs (1974) reported on one aspect of the "downward scan" in a study of the effects of diagonal markings painted on a sidewalk. They observed that the markings were "designed for aesthetic purposes and not intended to have any particular effect on behavior". Yet, they found that the sidewalk pattern was associated with reversals in the usual tendency of many pedestrians to walk on the right-hand side of the sidewalk. This effect was especially marked in
the case of women, suggesting that female pedestrians may devote more
time looking downward as they walk. Three possible explanations were
offered for this possibility:

(1) Women walk more slowly on average and thus may have more
time to perform a downward scan,

(2) Women may want to avoid the gazes of male pedestrians and
thus look downward more often than men, and/or

(3) The characteristics of footwear worn by many women (e.g., "heels") may require more attention to the walking surface.

Golson and Dabbs have thus opened the question of differential
scanning by women and men. However, more research and observation are
required before a full understanding of this process will be available.
It is also unknown what other factors may affect environmental scan­
ning, but clearly the quality of the environment itself must be con­
sidered. Korte and Grant (1980) found, for example, that:

... the sight and sound of dense traffic can pre­
clude pedestrians' noticing peripheral elements of the
environments they are passing through, if not major
elements as well. (p. 417).

The work involved in scanning while navigating the pedestrian vehicle
is generally unnoticed by the "pilot". This process is largely auto­
nomic, but the tensions it creates, if too much attention to scanning
is required, can be exposed through careful interviewing. Stilitz
(1970) reported that pedestrians said they became "irritated" when
they had "to pay attention" during crowded sidewalk conditions.
The pedestrian processes large amounts of sensory input. As this processing is often autonomic, the pedestrian rarely reflects upon it. Rapoport (1977) has provided a comprehensive survey of multisensory inputs to environmental perception. Noting that designers and planners tend to emphasize the visual aspects of the environment, he underscores the importance of sound, tactile sensations, kinesthetics, air movement, temperature, and smell. Information received through all these channels from physical as well as social sources must be woven into an image of a particular environment before one can effectively navigate in it.

Some environments appear much more coherent and understandable than others and Rapoport calls these "complex" environments. Theoretically, they are neither too confusing nor too bland or boring. The elements that go into making an environment pleasingly and effectively complex lie beyond the scope of the present study, however. It is important to observe that at present there is no operational method for determining the complexity of an environment defined in these terms. It is also worth noting that the speed with which one travels through an environment has a definite effect on whether the environment is seen as complex or not, at least according to Rapoport's theory. This point would be especially crucial when a given environment is intended for use by a variety of vehicles which normally travel at much different speeds, e.g., automobiles and pedestrians. Rapoport observes:

... an environment comfortably stimulating from a
The car becomes monotonously boring on foot while what is interesting on foot becomes chaotic in a car. The two environments need to be quite different in terms of noticeable differences and perceptual organization: at high speeds one needs distant views, simplicity and large-scale while at slow speeds one needs small-scale, intricacy and complexity. (pp. 242-43).

Further, he notes that the pedestrian can much more easily slow down, even stop, to take a careful look at a particular environment. The motorist, especially in large cities, can rarely do this:

Motorists' perception is affected by the length of time each element is in view and also the criticality of the task. The pedestrian has each element in view as long as he wishes and can satisfy his interest in it because of the low criticality of this task. When pedestrians are harassed by traffic their task becomes critical and they cannot perceive the environment in the way appropriate to their speed--this is a common problem. (p. 243).

It is not known whether the different velocities reported for various classes of pedestrians are sufficiently different so that they would have differential perceptions of complexity in the environment. It is also not known if some pedestrians might actually adjust their walking speeds in an attempt to influence the degree of complexity with which they must contend.

In sum, the pedestrian can be seen as the pilot of a very special vehicle. It is flexible and always convenient, readily survives "crashes" with vehicles of the same type, does not in-itself normally require sophisticated traffic control devices or high-cost freeways, and engages in autonomic environmental scanning and information
susceptible to the pedestrian. The pedestrian is able to appreciate far more fine-grained detail in the environment than is the motorist. But beyond this, the pedestrian experience is almost always a social one.

The Social Context of Walking

Whereas Goffman introduced the concept of the individual pedestrian as a "vehicular unit", Wolff (1973) developed the notion of a "coordinate" to describe people who become part of "public orderings" such as the pedestrian traffic system. He wrote:

First, as a noun, "coordinate" describes individuals in such systems as occupying related points within a patterned array. The mere physical copresence of individuals establishes them as coordinates—as are trees, pillars, curbs, and walls. The relationship between (groupings or sets of) coordinates in a patterned array (in other words, opposing lanes, clusters, queues) guides the behavior of the individuals in that field. In addition, because they are mobile and flexible, individuals are potentially facilitators as well as obstructors of each other's progress. The term coordinate as a verb describes the normative baseline requirement for encounters in the public order on the facilitate-obstruct dimension: equal responsibility for equal effort for common progress. (p. 47).

"Cooperation" is a key element for understanding the social context of pedestrian behavior. Wolff wrote that "a high degree of cooperation is an intrinsic part of pedestrian behavior—without it walking would be impossible" (p. 46). As members of a public order or "coordinate" whose members are travelling in opposite directions, one of the most basic social tasks which must be performed is the "simple" one of not bumping into each other. Most pedestrians expect each other to be
cooperative rather than obstructive in the completion of this task.

A strategy which functions to reduce collisions is the process of "streaming" as observed by Older (1968). He found that proportions of total flow in either direction on a sidewalk had little or no effect on pedestrian velocity. He suggested that:

It is thought that this lack of effect is due to the considerable development of "streaming", i.e. the tendency for pedestrians travelling in the same direction to follow one another in files which interweave with those from the opposite direction. This reduces the interaction between the two flows, so also does a natural tendency for pedestrians to keep to the right. Although it was seen to occur no measure of the extent of "streaming" was devised in this study. (p. 162).

Clustering, platooning, and streaming have been found to be complex phenomena. The "natural" tendency for keeping to the right that Older observed above is, in fact, a rule or norm which is early socialized in walkers. This social component of pedestrian behavior is revealed in the following analysis of Matson's pedestrian skill learning program.

Matson (1980) reports on efforts to teach mentally retarded children how to be "successful" pedestrians. The plan is based on the idea of breaking down the act of walking into minor behavioral units which can then be taught one by one and then finally combined into sequential patterns. Despite the behavioristic framework of the proposal, the implicit social nature of walking becomes explicit when each of Matson's behavioral objectives is given close examination.
Matson defines proper sidewalk behavior as walking on:

... the correct side of the walkway in a socially appropriate manner such that no disruptions in pedestrian traffic flow or social disruptions to other pedestrians were created. (p. 100).

The specific tasks each youngster must first learn include:

(a) The subject walks on the right side of the sidewalk.
(b) The subject does not bump into other pedestrians.
(c) The subject greets others when appropriate.
(d) The subject does not stare at others.
(e) The subject does not engage in inappropriate mannerisms. (p. 100).

Despite Matson's behavioristic approach to learning theory, it is clear from inspection of the above tasks that the young pedestrian is required to learn a very subtle, flexible, and complex set of social rules in order to be judged a competent walker. There is obviously much more to learning to walk than just putting one foot in front of the other.

These social norms are learned and applied with increasing skill as the pedestrian becomes an accomplished walker. Ryave and Schenkein (1974) set the foundation for an analysis of the "work" of walking in mature humans. Three major components form the core of their analytical framework:

(1) Navigation -- the basic ability to walk along a sidewalk without bumping into anyone or unintentionally walking between members of an oncoming group of pedestrians,
(2) Recognition work -- the process of identifying whether oncoming pedestrians are walking alone or are members of a group, and

(3) Production work -- the process of emitting signs readable by others to indicate whether one is walking alone or as part of a group.

This scheme recognizes that the problem of "not bumping into anyone" is compounded by the additional tasks of not only recognizing "singles" and "groups" but also producing or sending out signals indicative of group membership status. All of this, however, is predicated on the process of social scanning.

Goffman (1971) explicated "scanning" in this lengthy, but insightful quote:

The term "scanning" does not have to be defined, but the way it is done in pedestrian traffic needs to be described. When a pedestrian in American society walks down the street, he seems to make an assumption that those to the front of a close circle around him are ones whose course he must check up on, and those who are a person or two away or moving behind his sight-line can be tuned out. In brief, the individual, as he moves along, tends to maintain a scanning or check-out area. (By angling his own head so as not to be directly obstructed visually by the head of the pedestrian ahead of him, he can ensure his maintenance of this view). As oncomers enter the individual's scanning range--something like three or four sidewalk squares away--they are commonly glanced at briefly and thereafter disattended because their distance from him and their indicated rate and direction of movement imply that collision is not likely and that no perception by them of him is necessary for his easily avoiding collision. (pp. 11-12).

He also noted the particular shape of the scanning area:

... the scanning area is not a circle but an
When a pedestrian discovers an oncomer within the scanning oval, this information is acted upon in a patterned, but subtle, manner.

Goffman wrote that there are two "special moments" which occur during an encounter between two pedestrians. First, there is the emission of a "critical sign" or act which lets the other pedestrian know what you, as a pedestrian, intend to do next. These are frequently very subtle motions, the study of which is part of the evolving discipline of kinesics. It may be a straight-ahead glance or a small motion of the shoulder that tells the other pedestrian you are going to alter your course, and by how much, in order to avoid an impending collision.

Second, there is an "establishing point" or a recognition by both parties that they have exchanged "critical signs". This exchange and verification procedure would also include the group membership information discussed by Ryave and Sheinkein. This exchange and acknowledgement process is very subtle and complex, but millions of pedestrians do it daily without ever giving it a thought. It is only after the completion of these two "special moments", as Goffman named them, that actual changes in course are put into effect. Sometimes these messages become confused with the result that two opposing pedestrians may find themselves in a sort of reciprocal "dance" trying to figure out who is going to go which way. Tourists
in foreign lands, for example, may experience increased levels of "bumping into" others. This may be due, in part, to differences in "critical signs" from one culture to another which the tourist does not recognize or misinterprets, resulting in collisions and more frequent "near-misses".

Wolff (1973) was among the first researchers to investigate the "step and slide" movement which pedestrians use to adjust their paths to avoid collision after the "establishing point" has been reached when sidewalks are crowded:

... at higher densities a common behavior, especially between members of the same sex, was not total detour and avoidance of contact but a slight angling of the body, a turning of the shoulder and an almost imperceptible side step--a sort of step-and-slide. When a pedestrian executed a step-and-slide, he did not move enough out of the path of the oncoming pedestrian to totally avoid contact or bumping; for a clean "pass" to occur, the cooperation of the other pedestrian was required and given. However, even when the step-and-slide was properly executed, some body contact, such as brushing the shoulders, chest, arms, or hip area, almost always occurred, while the hands were pulled inward or away to avoid hand-to-hand contact. (p. 39).

Even when people cooperate, however, they may not like the fact that they have to do so.

Using half-hour, semi-structured interviews, Stilitz (1970) investigated the reported experiences of 24 people who walked to work everyday. He observed that the subjects seemed always in a "hurry" when walking and this condition may have influenced the following results. In any event, he found in general that:
People disliked the forceful physical contact experienced under the most extreme conditions. Under less extreme conditions, they were irritated by delay. Under conditions where potential delay could be avoided, they were inconvenienced by the necessity of taking avoiding action. (p. 71).

Clearly, touching, brushing, and collision are not considered enjoyable situations and the cooperations of all pedestrians in avoiding them is a general expectation, at least in American society.

Sobel and Lillith (1975) instructed experimenters to walk straight at moving pedestrians on a New York Sidewalk without stopping unless "a direct frontal collision was imminent". They found that collision situations never occurred because the observed subject always made a correction or side-step to prevent collision. Interestingly, however, they report a very high number of slight collisions or "brushes" even though the sidewalk density conditions were not high. They suggest that subjects "refused to give up unilaterally their right of way until the very last moment" and concluded that this indicates a strong "norm of bilateral accommodation in street behavior" (p. 44). That is, unilateral withdrawal from potential conflict is not expected. Rather, cooperation is anticipated and it could be hypothesized that the "brush" may sometimes serve to remind the offender of a failure to yield at least a little.

Availability of walking space on a sidewalk is a prerequisite if forward progress is to be achieved. Several factors enter into the amount of space made available under various sidewalk conditions. Dabbs and Stokes (1975) observed 470 pedestrians and found that
pedestrians travelling in groups are given wider berth than are pedestrians walking alone. Further, other pedestrians accord more space to approaching males than to females. Adding to their list of findings, they also reported that culturally defined "beautiful" women were given more space than "unattractive" women. The authors concluded that "sex, number, and attractiveness may be regarded as aspects of power" which enter into even the most "simple" human interaction of meeting and passing oncoming pedestrians on public streets.

But, do the above findings mean that "power plays" are frequent events for pedestrians? Sobel and Lillith (1975) observed that women are generally given wider berth than men when passed by oncoming pedestrians. Observing 3141 pedestrians, Willis and others (1977) suggested that "power" may not be so important as "gallantry" in deciding who moves where during collision avoidance maneuvers. They found:

Persons or groups moved for larger groups and younger groups tended to move for older groups, but women did not tend to move for men nor did blacks tend to move for whites. (p. 38).

Further, they go on to suggest that "maneuverability" may be the main issue:

It is easier for smaller groups to move for larger ones, as it is easier to move for those who are not carrying an infant, not handicapped, and not maneuvering a wheelchair or stroller. (p. 38).
These authors remind the reader that in appearance, it may look the same when someone yields to someone with greater power as when someone in power is required by social convention to give deference to a culturally defined "weaker" person. The point to be drawn from these studies is that issues of convention, power, and deference appear to be at work on the sidewalk, but that the relative importance of each is still open for discussion and study.

The foregoing examples help to elucidate the assertion that "walking down the street" is not a simple, behavioristic exercise. It involves sophisticated signal exchanges and normative behavior when pedestrians meet each other from different directions and must negotiate rights-of-way. The social aspects of walking, however, also include the experiences of people who walk together, in groups.

**Walking in a Social Group**

If little is actually known about the signal exchanges and social norms involved in walking, even less is known concerning how pedestrians proceed as members of social groups. Berkowitz (1971) made one of the only cross-cultural observations of pedestrians and, interestingly, he focused on the question of behavior in groups. Observing pedestrians in six countries, he reported that:

1. The tendency for pedestrians to travel in groups was highest in the Moslem countries, England and West Germany. It was lowest in Italy and the United States, and

2. Pedestrians in the United States tend to be much less
sociable with each other as measured on three sociability dimensions. The walking mode provides opportunities for socializing and friendly exchange, goals which may often have as much, if not more, value than actually getting to a particular destination. Yet, it appears that pedestrians in the United States are not utilizing the full potential of this aspect of pedestrian travel.

The walking habits of sub-human animals raise some interesting questions about group walking. Extrapolation from such studies is, of course, tricky at best and should generally be restricted to suggesting areas of inquiry which must then be reformulated in human terms. One such study was recently completed by Rhine and others (1980) on the walking habits of troops of baboons. They observed that infants were protected by being placed at "the center of their troop" when baboons travel as a group. Thus, it is interesting to speculate about spatial placement rules, if any, for walking humans.

There are some norms which may provide clues for more detailed study. For example, males in Western cultures tend to take the street side of the sidewalk when walking with females (Goffman, 1971). Various cultures prescribe that females walk behind males. Contemporary changes, if any, in these norms as well as questions about the possibility of real but unrecognized additional rules for the spatial structuring of human walking groups remain open for study.

With regard to human infants, Wolff (1973) noted that adult human pedestrians often treat children under seven years old as "baggage". He observed:
First, many of the people who were holding the hands of children appeared to be dragging them through traffic. The child trailed somewhat behind and was continually buffeted by oncoming pedestrians with no major objections, verbal or otherwise, issuing from the child or the accompanying adult. Second, it appeared that the oncoming pedestrians would "sight" the adult and negotiate the right-of-way with him; the child would be led, ignorant of where his next step should be and sometimes stumbling over himself and others. Third, it appeared that, for the most part, the child did not "attend to" the oncoming pedestrians. (p. 45).

He concluded that several questions remain open for future observation:

Several empirical questions can be generated from these observations. At what age or stage of development have children learned to negotiate right-of-way, territorial possession, and so forth, in public places? At what age or under what conditions is their attempted use of such knowledge "respected"? (p. 45).

The answers would clearly provide insight into the time of a literal "rite of passage". The child obviously looks to the parent for help in doing the work of walking but also learns a complex set of social norms that make walking possible, both in groups and alone.

*The Macro-Sociology of Modal Choice*

Behavioral geography has long looked to psychological constructs to explain human spatial behavior. Such psychological processes have been noted above and will be discussed below in even more detail. It would be a mistake, however, not to at least devote a brief considera-
tion to the dynamics of macro-sociological forces on pedestrian behavior. This is especially true since the studies cited above have generally tended to fall into the dangers of "psychologism, i.e., the examining of complex social and historical developments from the viewpoint of individual psychological processes" (Rieser, 1973: 205). A relevant example, chosen from more deserving candidates, is a statement by Hartgen (1974) that:

The urban traveller's mode choice results from his evaluation of the perceived attributes of alternative modes, within situational constraints imposed on the individual and his household. (p. 378).

While the above hypothesis at least opens the door to consideration of "situational constraints", it is still psychologically oriented. There is much to be done toward a close examination of the reasons why many people "choose" to travel in the walking mode. It is important to realize that Hartgen (1974) found situational variables (e.g., income, automobile availability, etc.) far more explanatory than "attitudes" toward modes in determining modal choice.

Despite the representativeness of the pedestrian population, it is not a mirror image of American society. The elderly, the handicapped, the very young, the impoverished, and women are consistently overrepresented in samples of pedestrians. Members of these "special groups" endure real problems of spatial/environmental inequality which have rarely been addressed in the literature (the work of Paaswell, 1973; Paaswell and Recker, 1974; and Ballard, 1967, are important
exceptions). Insensitivity to these issues can result in seriously flawed planning for pedestrians.

A particularly forceful example of a failure to appreciate the macro-sociological context within which many pedestrians must actually function was encountered by the present author in 1981 when he was invited to participate in a review of the pedestrian research program proposed by the U.S. National Highway Traffic Safety Administration. NHTSA officials presented a color television spot which was to educate children about the "correct" way to cross streets. The film used blue and red symbols to indicate "good" and "bad" choices. The present author inquired if children could distinguish these symbols when the spot was received on a black and white (rather than color) television set. This inquiry was quickly dispatched with the summary observation: "Hell, everybody has color television sets these days, so no sweat". The safety education needs of pedestrians who cannot afford color television sets had not entered the consciousness of NHTSA officials.

The real needs and problems of pedestrians who have no other choice than walking as a transport mode (often for socio-economic reasons) have received virtually no attention. Unfortunately, this is not surprising when one examines the social status of the groups in question: they are among the powerless and ignored who suffer from many additional forms of discrimination as well. Although not given central attention in the present research project, it is clear that macro-sociological studies of the full-time pedestrian are long overdue.
Crossing the Street

The question of "crossing the road" is explored briefly in this section. This skill represents the next hierarchical component of spatial ability in the pedestrian. The ability to cross the street means that a youngster is no longer bound to his or her "home block". Children who know how to cross streets are allowed to visit their friends on the "next" block and to walk to school on their own without supervision. In short, they have mastered an essential ingredient in their ever increasing spatial freedom.

Beyond the obvious safety issues and questions (cf., Flynn, 1977, for the major safety references), street crossings provide an environmental setting which interests the social scientist in its own right. The following examples will be discussed below in greater detail but are introduced here to show the range of issues which may be studied in street intersections. Wagner (in press) finds street crossings to be filled with many unanticipated examples of cooperation and trust between perfect strangers. Ribey (1979) sees the act of crossing a street as a paradigm example of micro-decision-making. Several others have examined jaywalking as a function of conformity, status, and other rules for normative behavior. Hill (1979) views the urban street intersection as a complex system which serves as an example for an holistic approach to urban design and environmental theory construction.

The diversity and complexity encountered in the urban street intersection can be seen as a challenging theoretical puzzle. Hill and
Roemer (1977) expressed the following sentiment:

Whereas a focus on the urban intersection may seem, to some readers, superficial and not worthy of theoretical effort, one finds on examination that this system is complex enough to challenge the ablest theoretician when viewed from a theoretically explanatory perspective. The definition of the traffic intersection system and its component elements, together with an explication of element interactions, reveals nearly intractable problems when approached explicitly in a manner designed to provide a theoretical sense of understanding of behavior within the system as a whole. Even an examination of a subset of this behavior, pedestrian compliance, discloses a theoretical briar patch. It is obvious that the street intersection system is a "simple" system in comparison to the larger urban system of which it is a part, but it is still complex enough to provide many tough and instructive theoretical puzzles. (p. 343).

Apart from a plethora of "safety" literature in which the problem of crossing streets is often reduced to educational and behavioristic banality, this aspect of the pedestrian experience has received strikingly little study as a subject in its own right.

**Related Street Crossing Literature**

The express purpose of this section is to note several studies which relate to street crossing behavior but have not examined this behavior as an experience-in-itself *per se*. Behavioristically-framed approaches for teaching children how to cross streets are found in Matson (1980) and Page and colleagues (1976). Various programs to train students to cross streets safely have been implemented in a number of schools. Evaluation of these programs still remains problematic, however. The necessary evaluation research has generally been
framed in behavioristic terms which are insensitive to the subtle fac-
tors involved in the decision to cross a street. The research designs
themselves often raise more questions than they solve. For example, 
the results reported by Yeaton and Bailey (1978) are clouded due to 
small sample sizes (ten in one group, only four in another); special 
treatment of experimental groups ("children were released from school 
approximately 15 min early each day"); and knowledge by the subjects 
that they were under observation (the children "were accompanied to 
the street corner. They received the simple instruction: 'Now I want 
to see how you cross the street when the crossing guard holds traffic!' 
[p. 322]). These threats to validity (cf., Campbell and Stanley, 1963) 
hurt the interpretation of an otherwise admirable attempt to document 
the effects of a presumably worthwhile safety education program. This 
is not an isolated example, unfortunately. The pedestrian safety com-
munity has been slow to undertake the difficult process of objectively 
evaluating the performance of its safety programs and proposals.

Several observers have noted considerable variations in the man-
ner in which different categories of pedestrians cross streets. The 
degree to which these differences are innate, socialized, or adaptive 
is still a relatively open question. Repeated observers have found 
that women, pedestrians in groups, and the elderly tend to cross 
streets more slowly than men, pedestrians walking alone, and the young. 
It has also been frequently observed that women and older pedestrians 
also tend to engage in less jaywalking than do men and younger pedes-
trians.
Interpretation of such findings is sometimes difficult and problematic, however. Although it is often assumed that females, for example, are socialized to be more compliant and law abiding, there are no studies which have investigated whether reduced jaywalking by women is simply a rational, adaptive response to drivers who may try to claim rights-of-way over female pedestrians. Such inquiry is clearly indicated by research conducted by Henderson and Lyons (1972) who found that the walking velocities of females are more frequently disturbed than those of males when crossing at a traffic intersection. They offered the hypothesis that:

... a motorist finds it much easier to perturb the motion of a female pedestrian on a zebra crossing than that of a male. (p. 355).

Although based on observations in England, this suggestion lends itself to an "intimidation" thesis. Under this conceptualization, motorists, especially men, may attempt to "force the issue" rather than yield when they identify what they perceive to be a less combative competitor for "right-of-way" in an intersection. This hypothesis would be consistent with the finding by Katz, Zaidel, and Elgrishi (1975) that females and older drivers slow down more than other drivers when they approach an intersection.

Sexist attitudes are not restricted to the street, however. They sometimes exist in the research literature itself. Collett and Marsh (1974), for example, observed the manner in which women moved when crossing streets and offered the astounding hypothesis that:
We therefore require some explanation of why women loathe to orient toward oncoming pedestrians. Put in these terms, an explanation is not difficult to find: the obvious assumption to make is that women are concerned to protect their breasts. (p. 288, italics added).

In their rush to prove this thesis, the authors failed to suggest that women may simply be trying to avoid the uninvited gazes and body brushes initiated by men. Nor do they discuss the possibility that males are overly "frontal" or "aggressive", hypotheses that are equally "obvious". This example demonstrates that future work on hypotheses concerning age and sex specific socialization for explaining variations in street crossing behavior requires researchers to divest themselves of sex and age biases.

Jaywalking or crossing the street against the light has been used by social scientists as an index of "conformity" to social norms. While interesting, these studies are generally more concerned with theoretical issues surrounding the concept of "conformity" than they are with the behavior of pedestrians specifically. Pedestrian compliance has been studied by Lefkowitz and others (1955); Dannick (1973); Russell and others (1976); Hill and Roemer (1977); and Alexander and Federbar (1978). The research question generally put is: What factors will increase the likelihood that a pedestrian will fail to conform to prohibitions against jaywalking? Most findings support the idea that a given pedestrian will be more likely to jaywalk if he/she sees another pedestrian jaywalk. This tendency increases if the jaywalking model is perceived to have high social status.
Although jaywalking studies concern a behavior which increases risk of injury due to collision with an automobile, relatively few researchers have examined interactions between pedestrians and car drivers specifically. Due to the rarity of physical collision between pedestrians and automobiles during any given observation period of a few hours or so, behaviorist safety researchers simply conceptualize "risky behaviors" on the part of pedestrians rather than actually observe what happens in an actual pedestrian/automobile collision. The present author does not advocate real-life observation of tragic accidents which might otherwise be prevented, but the lack of empirical reference for behaviorist assertions about "pedestrian errors" is both methodologically and theoretically disconcerting (especially given the behaviorists' own stringent demands for solid empiricism). However, Katz, Zaidel, and Elgrishi (1975) conducted an innovative, controlled field experiment in which trained researchers assumed roles as pedestrians and initiated crossing negotiations as drivers approached a street intersection. These experimenters took somewhat of a risk to walk bravely in front of oncoming vehicles, but their results are exceptionally interesting. They found that drivers stopped or reduced their speed for crossing pedestrians more often when:

(1) The approach speed of the vehicle was low; (2) the crossing took place on a marked crosswalk; (3) there was a relatively long distance between the vehicle and the pedestrian's point of entry into the road; (4) a group of pedestrians, rather than an individual, attempted to cross; and (5) the pedestrian did not look at the approaching vehicle. Additionally, female drivers and older drivers slowed
down more than other drivers. (p. 514, italics added).

These findings were especially interesting in light of the fact that:

Pedestrian safety propaganda urges people to look left and right and again left before crossing, and then to keep looking at the approaching car. (p. 516).

If the pedestrian pretend not to look at the driver (but does so only out of the corner of the eye), he/she may have a better chance of getting the driver to yield to his/her legal right-of-way. Such "games" indicate the sophistication and subtlety of pedestrian behavior which is often missed in behavioristic safety research. The experimenters cited above took risks to obtain their findings, but each pedestrian is required to take similar risks every time a street crossing is effected. The process of risk estimation is both fascinating and subtle.

Risk Estimation and Street Crossing

It may be that pedestrians take a risk of getting "lost" whenever they start a trip, but they take a much higher risk in being struck down by an automobile. The assessment of this risk can be viewed from both macro- and micro-perspectives. Goodwin and Hutchinson (1977) examined the question of "risk" to pedestrians from a macro-perspective.

These researchers defined "risk" in terms of an index of the following form: Number of Accidents/Exposure to Danger. Quantitatively, they employed an estimate of "time spent walking" as a proxy measure of
"exposure". This definition is conceptually weak since walking per se is not particularly risky. Recall, for example, Goffman's (1971) observation that pedestrians can "bump" into each other with very little damage. The source of risk during walking derives from the potential of being struck by an automobile, specifically while crossing a street. Thus, a study by Routledge and others (1974) in which risk was estimated as a function of (1) number of roads crossed and (2) traffic density on those roads is much more satisfying conceptually. Unfortunately, Routledge and associates dealt only with children whereas Goodwin and Hutchinson attempted a more universal estimate of risk for the general population.

The latter authors based their conclusions on data derived from the National Travel Survey 1972/73 conducted in the United Kingdom. They warn the reader, however, that the walking data may well be underestimated. The same problem plagues the road accident data which were obtained from the Transport and Road Research Laboratory. Problems of interpretation thus resulted:

While walking and accident data are therefore likely to be underestimated, possibly by a similar order of magnitude, it cannot be assumed that the composition of these biases either match or offset each other. (p. 219).

Thus, this macro-view is built on a questionable data base. Nonetheless, the following is the best guess available. Comparing the overall risk of walking compared with other modes, they found that pedestrians are estimated to experience 19 deaths for every 100 million
miles walked. Car drivers on the other hand experience only 1.5
deaths for every 100 million miles driven. There is a flaw in logic,
however, in conceptualizing the problem in this way. The risk in
both cases stems from the same cause: automobiles. Left to its own
devices, the pedestrian mode is obviously much safer than most other
forms of transport. It should also be underscored that the death
rate per mile computed above is based on other assumptions which may
be inappropriate. The authors themselves noted:

If it is thought that 2.4 miles/h is an implausibly slow average pedestrian speed, and it is instead assumed that people walk for 20.2 minutes per day at an average of 3 miles/h, the pedestrian accident rates are reduced by 20%. (p. 228).

This example illustrates the difficulty of estimating risk at the macro-level. This is due in part to a real lack of reliable information on walking habits and walking environments. Further, more plausible conceptualizations like the one utilized by Routledge and colleagues should be pursued. Researchers should also distinguish between the risks incurred by walking per se (e.g., falling down, muscle strain, blisters, etc.) and other risks, such as muggings and being struck down by automobile drivers. Finally, there is little information available which indicates the extent to which risk is judged so high by potential pedestrians that they fail to become actual pedestrians.
Risk may also be viewed from the micro-perspective, i.e., from the level of the individual pedestrian who crosses the street. It could be assumed that the riskiness of streets could influence an individual's decision to choose one route rather than another. Thus, this discussion is more relevant to the current project than may first be evident. However, there is virtually no empirical research available which is not tainted by behaviorist assumptions about what constitutes "risk". A summary of research by Kastenbaum and Briscoe (1976) indicated that individuals who engage in more risky behaviors have somewhat different personalities than those who follow less risky courses of action. These researchers ranked 125 pedestrians as to the risk they took in crossing streets and then interviewed them. They found risky crossers "neither wanted nor expected to live as long as did the cautious pedestrians" (p. 33). Additionally, they reported that the "safest" pedestrians "were more aware of their actions and considered themselves safer, more self-protecting people generally" (p. 33).

These findings are certainly interesting, but the reader should again be aware of the potential behaviorist bias in their study. The summary of the research states:

The researchers judged risk on the basis of such factors as whether or not the subject watched the traffic lights, kept an eye out for oncoming cars and stayed within the crosswalk or scurried from behind parked cars and other indications of recklessness or caution. (p. 33).

The problem here is that "recklessness" and "caution" are being
judged on the basis of outward behaviors which can be judged "risky" or "not risky" only if the researcher is willing to accept certain assumptions about the legitimacy of introducing lethal machines into the pedestrian environment. For example, one can conceptualize "darting out" across the street without looking for cars as a more "natural" action that was reasonably "safe" until the widespread introduction of automobiles. Hence, it is the automobile which makes the behavior "risky", not some innate quality of the behavior itself. Politically, the "safe" crosser can be seen as one who cowers in defeat in the face of the oncoming automobile and who thus contributes to the continued dominance of the technological age. Regardless of this "framework" issue, the real point is that there is very little information available concerning the risk assessment skills of the pedestrian.

Two relevant conceptualizations or theories of risk assessment, however, have been proposed but they remain without empirical validation in any complete sense. Ribey (1979) examines the problem of crossing streets at mid-block rather than at marked intersections. He conceptualizes the decision to cross the street as a "microdecision" in which the pedestrian is always calculating risks and benefits of multi-channeled courses of action. His basic idea holds that the "legal trajectory" (i.e., the path prescribed by legal codes, e.g., crossing only at marked intersections) of the pedestrian is frequently incongruent with the "free trajectory" (which Ribey illustrates as a direct, least-effort desire line). Each trajectory or path represents
a different strategy for crossing the street. Each has different costs or risks and is built on very different value assumptions. In addition, the weights assigned to each decision change as each situation changes. For example, taking the "free trajectory" may save time for the pedestrian who is late for a business meeting. It might allow him/her to catch a bus he/she would otherwise miss. It could permit catching up with a friend he/she wanted to speak to. The more such "advantages" occur at the same time, the higher the calculated benefit of choosing the "free trajectory". Thus, even a law-abiding, "model" citizen may ignore the "legal" path when the advantages of the "free trajectory" reach a certain level of acceptability.

Ribey proposes, however, that few people use pure strategies. Instead, they employ "mixed" ones. This is held to result in the actual selection of what Ribey calls the "human trajectory". This path conforms to neither the "legal" nor the "free" paths. This "human" path across the street is said to be a compromise path which results in a "trajectory" which combines elements of both the legal and free options. It is an open question as to whether such a compromise path is viewed as a satisfactory one by the pedestrian, since the route chosen is neither particularly safe nor is it the shortest. Ribey's observation data confirm that people do appear to take the "human trajectory", but it is not yet demonstrated that they do so as a result of the "calculations" which Ribey proposes as an explanation.
Hill (1979) proposes a generalized systems approach to the urban intersection in which risk assessment becomes an important process. Demonstrating how to articulate the full array of relevant elements required for a functional definition of an urban intersection, this paper ends with a brief scenario or theory sketch of how a lone pedestrian approaches the problem of risk assessment before crossing the street. An independent, observational study by Wagner (in press) parallels several of Hill's ideas and provides empirical support for Hill's proposed environmental interrogation process. Wagner, however, extends his observations to include the behavior of pedestrians in groups as well as the behavior of the lone pedestrian. For this reason, Wagner's findings are presented in some detail.

**Social Roles and Risk Assessment**

This section considers the overlap of socialization issues with those of risk assessment. This presentation is based on the recent and insightful report by Jon Wagner (in press). His research is based on photographic images collected in downtown Chicago. In all, some 1,500 photographic images of pedestrians crossing streets were produced. His analysis reveals that three sources of environmentally-situated information are normally scanned by pedestrians prior to crossing the street. These sources or clues are: (1) traffic signals, (2) the street per se and traffic on the street, and (3) those people, if any, who may already be crossing the street or are about to.
Wagner's most interesting work concerns groups of pedestrians and the social roles they assume, but he also examines the case of the unaccompanied pedestrian. His photographic observations reveal the lone pedestrian scanning several sources of information:

With no one to help him out, he must read all three clues himself. Our observations indicate that he does just that, alternating his gaze between the "WALK" sign and the direction of oncoming traffic; and--if there are others waiting across the way--searching for other pedestrians to leave the curb and into the crosswalk.

Thus, Wagner's observational data are congruent with the theoretical systems analysis presented in Hill (1979). Wagner, however, goes beyond the theory-sketch of the lone pedestrian to examine manifestations of "coordinate" behavior.

Whereas Wagner observes that lone pedestrians scan several sources of information, he finds changes in this pattern when groups of pedestrians wait for the traffic signal to change. Among pedestrians in the "front line" of a group waiting to cross, an unexpected "division of labor" takes place. Some become "specialists" who look only at the traffic signal while other "specialists" keep tabs on the traffic in the street:

It is noteworthy that the front-liners themselves are about equally divided between those who look up the street and those who look at the light. The mechanism by which these two "observation roles" are assigned remains unclear. In our limited research efforts, we have been unable to find enough pursuable cases to determine if it is taken on anew at each street corner, or if it is an attribute of the individual pedestrian.
If this finding has wide applicability, then the process by which pedestrians divide observation tasks into distinct roles deserves considerably more study. The explanation of role assignment may lie in a socialization process, an hypothesis which suggests that the link between socialization and risk assessment processes may be deeper and less obvious than some psychologists would have the reader believe.

Pedestrians on the "front line" not only trust each other to perform their particular role (signal or traffic watching), the pedestrians in what Wagner calls the "backfield" trust the "front-liners" to make good decisions as to when to cross the street. The person in the backfield does not look at the signal or the traffic conditions, but just looks straight ahead at the back of a front-liner. The backfielder often relies completely on the judgment of a front-liner. Further, pedestrians who rush up to the crosswalk after the crossing process has already been initiated by others also put a good deal of trust in those who have gone before to have made the correct decision:

If someone approached an intersection and observed that its crosswalk had apparently-safe pedestrians already in it, the new arrival looked only at them. Rarely did this latecomer check his "safe" reading of the passage with either the traffic light or by glancing up the street to see if any traffic was moving into his path. The behavior of this pedestrian--who arrives on the scene when others are already preceding him across the street--is such that he seems to "trust" the anonymous others who appear before him in the crosswalk. He assumes that they are there for good reason, and he is willing to accept their actions within a context of "normal appearances".

Further research will surely spring from Wagner's astute discovery of
social differentiation within the ranks of street-crossing pedestrians. Not only is the research interesting to the student of pedestrians, it sheds valuable light on the question of trust among strangers. Wagner concludes:

Participation by strangers in an *ad hoc* division of labor is notable in and of itself. Cooperation between individuals in times of crisis and catastrophe provide a wealth of human interest news . . . While not nearly as newsworthy, the everyday practice of crossing streets shows a similar kind of differential social labor in the face of a common danger. In the roles of light-watcher, street-watcher and backfield, anonymous individuals have worked out a collective solution to one small part of their common fate.

The preceding review underscores the fact that there is much about pedestrian activity which in neither merely simple nor obvious. The questions generated by observing pedestrian behavior are far beyond the grasp of a single researcher, let alone a single research study. The separate issue of route selection by pedestrians, for example, is in itself a complex topic of which only minor aspects can be addressed in a study of this size.

**Choosing Routes**

This section concerns the most complex aspect of walking mode transportation: the selection of routes from one point to another. Choosing routes builds upon all the skills discussed in the preceding two sections: knowing how to walk and how to cross streets. Pedestrians engaged in moving through the environment may be searching for
some particular place, enjoying a pleasant walk, or engaged in a more or less autonomic trip to or from work, school, or shopping. Whatever the case, each pedestrian is presumed in this study to be making decisions about which specific route to take from among all the possible routes that could be taken. This decision process does not reveal itself easily to the researcher.

Selection of routes through a maze of alternatives is one of the distinguishing characteristics of mobility in an urbanized society. Moles and his colleagues (1977) observed that the labyrinthic image permeates modern life:

The labyrinthic situation is one of the tourist who discovers the charm of the Small Village in Alsace, the one of the housewife fluttering through the multitudinous shelves of the supermarket, the one of the elegant woman scouring Sacks Fifth Avenue or Sears from top to bottom, the one of the visitor awed by the science museum, of the motorist who discovers an unknown city. This is one of the most common occurrences of our life, precisely manifest in the ever increasing regulatory constraints of our society. Socialized life tends to be more and more like the vagrant existence in a maze of stone corridors described by Kafka and programmed by computers and bureaucracies. (p. 3).

Although this quotation has unfortunate sexist dimensions, its central point is well taken. Researchers have done little to explore the experiential aspects of life in urban mazes. The vast majority of research to-date has focused abstractly on pedestrian "flow" through urban areas.
Gravity Models and Pedestrian Flows

Within the planning community, heavy emphasis on the prediction of pedestrian behavior with a view toward practical application in pressing and immediate planning situations has led to the construction of several mathematical models of aggregate pedestrian flow. For the most part, these models are variations of a general interaction model called a "gravity model". These models are "powered" with empirical data which are usually collected in a "pedestrian count".

Gravity model predictions are generally based on counts of pedestrians passing or "flowing" past designated observation points during specified periods of time. The resulting flow predictions provided by the models are thus extrapolations of these counts. Emmons (1965) provided a useful manual for conducting such counts. A more up-to-date survey of counting methodology is found in Mellor (1976). Yates (1960) outlined a "moving observer" technique which permits the researcher to estimate the number of pedestrians present on a given length of sidewalk. More technologically sophisticated (and expensive) methods employ aerial photography for the purpose of obtaining an estimate of the number of pedestrians on all streets under study at approximately the same moment. The limitations and advantages of these techniques are further discussed, with examples, in Lautso and Murole (1974) and, more exhaustively, in Pushkarev and Zupan (1975).

The majority of flow models are based on gravity formulations. Haggett and his colleagues (1977) provide a useful and basic introduction to the gravity concept. In essence, the model holds that inter-
action is more likely between two pedestrian generators if the generators employ or have more pedestrians individually. Further, the concept suggests that interaction between two generators is decreased the further apart they are in space. In short, users of the gravity model attempt to predict how many pedestrians will "flow" between points A and B based on knowledge (or estimates) of how many pedestrians there are at points A and B and how much "distance" separates A and B. Such predictions may be conceptualized as either probabilistic or absolute. In practice, the level of predicted interactions using the basic or unmodified gravity model is rarely accurate. Initial attempts to improve the accuracy of the predictions usually involve the addition of an exponent to the distance term. Numerous other "refinements" are often proposed by the architects of gravity models, but the logic of these is most easily understood in reference to regression model versions of the basic gravity formulation. Regression techniques allow the planner to first state the basic ingredients: centrality and the pedestrian density at a given point. To this can then be added any number of additional factors such as time of day, day of week, retail floor space, number of restaurants within 100 feet, etc. With this additional information, the model's "fit" with empirically collected data is often dramatically improved to the point that many planners feel comfortable in using the predictions as estimates in their work. Excellent examples of the gravity approach and its regression extension are found in Haas and Morral (1967); Ness, Morral, and Hutchinson (1969);
Sandahl and Percival (1972); Lautso and Murole (1974); Scott (1974); and Pushkarev and Zupan (1975).

The flow models noted above (not all of which have been tested and calibrated) attempt to predict average flow of pedestrians on city sidewalks along the streets in central business districts. This allows planners to estimate potential changes in pedestrian flows resulting from planned locational changes in, or additions of, major points of origin and/or destination for pedestrians. While useful from this point of view, these models in fact do little to illuminate the nature of the individual pedestrian experience and are founded upon a static, status quo view of the world.

A major shortcoming of gravity and regression models employed in the planning community is that they reflect current situations because they are calibrated or "adjusted" using empirically collected data. Hence, future flows are predicted on the basis of present conditions. Innovative plans based on assumptions about behavior and/or experience which have no current referents in present situations cannot really be evaluated using this approach. Thus, gravity models tend to provide "more of the same" predictions which often become self-fulfilling prophesies. These and other problems and limitations of mathematical models used in traffic planning situations are reviewed in a monograph by Richardson and others (1979). In short, gravity model predictions are usually reified estimates bound up in past behavior patterns and structural constraints rather than insights which look forward to emancipatory challenges and possibilities.
Maps of pedestrian flow are usually abstracted from data collected at points, whereas the flow map purports to represent behavior along streets or lines. It is sometimes forgotten that this conceptual abstraction has taken place. In a very few studies, flow maps have been constructed using route data reported by pedestrians (e.g., Marchand, 1974; and Hartenstein and Iblher, 1967). The resulting maps unfortunately aggregate all of the individual routes in such a manner that the resulting diagrams are indistinguishable from ones constructed using point data. Although it is sometimes tempting to look at a flow map and observe that it illustrates the paths taken by pedestrians, one must quickly remind oneself that the map is an abstraction which is not at all informative about which routes are most favored or most utilized. It is the aggregate form of these maps which makes it very unlikely that they will ever shed much light on the reality of the pedestrian experience. This philosophical/methodological issue, called by some the "micro-macro debate", is discussed in depth by Cullen (1976) and Hudson (1976). It is a basic tenet of this study that far more attention should be given to the conceptualization and empirical investigation of route selection at the individual level. The time has passed for production of yet another model of undifferentiated aggregate level flows.
Route Notation Schemes

Although routes in this study are represented simply as lines and dots, other approaches should be noted. The problem of describing the environmental characteristics of a given route has been addressed in the fields of architecture and design. Several systems for graphically portraying what a pedestrian will see and experience along a particular route (often a route through a building) have been proposed (e.g., Halprin, 1965; Noe and Abernathy, 1966; Thiel, 1961; and Appleyard, Lynch, and Myer, 1964). These systems generally include a "travel line" which is augmented by other symbols indicating what is seen or experienced at various points along the route. In many ways, they are similar to "strip" maps. Other versions propose a series of sketches similar to frames in a movie. Thiel's work is probably the most comprehensive proposal and includes notations for variations in walking speeds, standing still, walking up or down, turns and the degree of angle, range of visual fields and the contents of these fields in terms of forms, enclosure, illumination, shadow, and color.

Appleyard, Lynch, and Myer also suggest notations for dealing with high-speed travel in an automobile and the apparent distortions which occur in visual fields at high speeds. Mitropoulos (1973, 1975) uses a series of sketches which focus on the form and enclosure of the spaces through which one might travel.

These notation proposals tend to be oriented toward future construction or designs. Their purpose is to give a client some feeling
of what it might be like to "move through" an as yet unbuilt project. In addition, preparation of the "movement script" reminds the designer to think about a project in dynamic rather than static terms.

A more general conceptualization has been advanced by Perin (1970). She introduced the "behavior circuit" as a unit of analysis for environmental designers and architects:

By behavior circuit I mean to denote both the movement and the completion integral to tasks, errands, recreation, work, visiting, and so on. . . . . what behavior circuits implies is an anthropological ergonomics, tracking people's behaviors through the fulfillment of their everyday purposes at the scale of the room, the house, the block, the neighborhood, the city in order to learn what resources--physical and human--are needed to support, facilitate, or enable them. (p. 78).

Perin's idea was development of a research tool which could be applied to inform the architect prior to design work rather than to illuminate dynamic aspects of a completed (but unbuilt) design proposal. Perin suggested noting the kinds of things that people do as they move about from place to place and then using this information to design better environments. Perin was particularly concerned with the behavior of pedestrians and noted that:

Having given priority to the automobile, planners give little thought to the resident as pedestrian. (p. 82).

The result of her concern was a call to designers to describe the sequence of events which unfolds as a pedestrian chooses and follows a route. Obviously, pedestrians may engage in a very wide range of
activities and events while engaged in a "behavior circuit". These may include shopping, visiting, helping, sightseeing, working, wandering, being lost, being surprised, marching in a parade, planning a revolution, grieving for a friend, exercising, dancing, escaping, etc. This study investigates a much more modest and restricted range of events: the sequence of route choice decisions a pedestrian makes when walking from one point to another.

Although not attempted in this study, it is also possible to focus on very minute aspects of pedestrian behavior. That is, how one swings one's arms, turns the head, or rotates the hips while walking along a given route. Such micro-aspects of walking could be described using notational schemes devised to record the movements of dancers. The completed notation is a "movement score" which is directly analogous to a musical score. This score can be read by trained dancers who can then re-create the intended movements just as a musician re-creates a musical passage by reading the notes on a sheet of music. The method proposed by Laban (1975) is one of the better known notation formats. To be useful to pedestrian behavior researchers, however, such a system would have to be adapted to allow the researcher to discriminate between subtle differences in walking behaviors which may not be part of "the language of dance". The dance metaphor is one worth exploring and has been employed on a macro-level in Seamon's (1979) concepts of "place and body choreographies" and "place ballet".
In summary, the notation schemes now available provide a way to wed the activities of pedestrians on "behavior circuits" with the pedestrians' experiences of particular routes. These techniques have found little common acceptance in the design community, however, although their promise and utility continues to be championed by vocal proponents, particularly by many members of the Environmental Design Research Association. It may be that the proposed notation schemes are too complex and ambitious for practical use. The system used in this study is exceptionally simple and uncomplicated. It is hoped that continued experimentation with these notational systems may someday be rewarded with a richer understanding of the world and activities of the urban pedestrian.

*Alternatives to Gravity Model Approaches to Route Selection*

Several attempts to explore the route-choosing behavior of pedestrians are briefly identified and reviewed in this section. All of these studies have adopted approaches which are alternatives to the gravity model. It should also be noted that there are several existing studies which relate to route choices by automobile drivers (e.g., Michaels, 1965; Carr and Schissler, 1969; Benshoof, 1970; Colony, 1970; Gordon and Wood, 1970; and Jones, 1972) but which have little relevance to the decisions made by the pilots of Goffman's "pedestrian vehicle".
Environmental Preference and Route Choice: The first alternative approach to the gravity model is based on the idea of "preference". For example, it can be assumed that when pedestrians have a choice between routes of equal length all going to the same destination, they will choose the one which they find more "attractive" in one way or another. By choosing a particular route, the pedestrian could be said to express a preference for a particular combination of environmental attributes, both physical and social. Rapoport (1977) provides an outstanding review of the environmental evaluation and preference literature (see especially pp. 48-107). Pendakur and Brown (1970), Bishop (1975), Lautso and Murole (1974), and Underwood (1975) have adopted this approach in looking specifically at preferences for urban streets.

Blivice (1974), however, took this tactic one step further and attempted to link the environmental preferences of adults with their reported route choices. He asked respondents in a questionnaire study to note the walking segment of their last trip on a map. Each designated path was described by three composite dimensions: (1) greenness, (2) scale, and (3) pleasure. This study of purposeful, "walking to work trips" in Munich, West Germany, resulted in the following conclusion:

It has been shown that in general people tend to choose exposed places in the city which afford various kinds of views rather than enclosed areas such as arcades and narrow streets, seek out pleasurable environments such as plazas and green-islands and choose pathways lined with activities
which are thronged with people, especially the pedestrian mall, rather than seek out the quieter parks and tree-lined streets.

It should be kept in mind, however, that describing the paths people report taking does not mean that those people chose those paths because of the characteristics (e.g., greenness or scale) which the researcher feels are descriptive of the paths. The paths may have been chosen for completely different reasons. Thus, it is important that Blivice also asked his respondents why they chose their particular routes. The reasons most frequently cited were: (1) shortest path, (2) relative quiet, (3) greenery, (4) window displays in shops, and (5) safety. He also found that those who said they walked in order to experience the environment also reported taking paths that tended to be separated (as much as is possible in a city) from vehicular traffic corridors. Unfortunately, the aesthetic biases and sophistication of those who responded to the questionnaire are not known. Generalization of Blivice's findings is clouded by the possibility that cultural variations may exist in what is given preference in the walking environment. In sum, Blivice took the first needed steps in linking environmental preference concepts to route choice. His findings, however, give rise to new questions rather than establish preferences as an explanatory agency in route choice.

Route Learning as Socialization: It might also be assumed that there is a certain amount of training or socialization that goes into route-choosing behavior. Most young children, for example, are shown
the way to school by adults or older children. During this process, a child would not only learn a particular route, but would also begin to learn something about what makes for a "good" route. Very little, however, is known about how people learn routes through the real world. There is a considerable body of laboratory research on spatial learning in both humans and rats (e.g., Morton, 1949; Simon, 1957; and Olton and Samuelson, 1976), but the reader is advised that little of this work is directly related to the problem of route selection in urban areas. For example, Beth Kerr (1975) completed a laboratory investigation of processing demands during movement. In response to an inquiry from the present author concerning the applicability of her findings to the larger environment beyond the laboratory, she replied:

In response to your question on processing demands for pedestrians: the jump from micro to macro for motor processes is not an appropriate one, as far as I'm concerned. (Kerr, 1977).

Thus, what little can be abstracted from such studies must be heavily "interpreted" before it is applied to the pedestrian environment in urban areas.

One of the few studies which directly examined socialization patterns was a questionnaire study by Reiss (1977). He inquired about the routes selected by school children (ages 5-14 years old). It was found that males more often said they chose the route taken to school because it is the "shortest" way. On the other hand, females more often said they "choose the route taken to school because they are
taken by parents" and "would go a different way if told to do so by parents or if it was 'safer'" (p. 42). It was also noted that older students more often report taking the shortest route and would "take the route that avoids traffic" and "would take a different route to school if told by parents or school officials" (p. 43). Based on these and other results reported in the paper, including behavioral observation of street crossing behavior, Reiss concluded that:

The pattern of responses shows a progression in pedestrian capability from the kindergarteners to the eighth graders. (p. 43).

These findings support the conclusion that children report being influenced by parents and peers in the selection of routes, a definite indication of socialization at work.

Yet, Reiss' work provides a good example for noting the variations that can occur when comparing "reported" behavior with "actual" behavior. It is quite possible that students also quickly learn to say the "correct" response while they in fact behave quite differently. Hence, the results reported by Reiss concerning route choice may represent socialized responses rather than socialized route learning behavior.

A study by Routledge and colleagues (1974) found that the information provided by school children is often more reliable than that provided by parents when asked to estimate the extent to which the children are exposed to risk during the journey to and from school. This suggests that young children may gain the capacity for
evaluating and judging routes rather quickly. How much of this skill is directly learned through socialization and how much might be a latent property of cognitive development is not known at this time. The truth, perhaps, may lie somewhere between these and other possibilities.

**Cognitive Aspects of Route Choice:** It can also be argued that the selection of a route depends on the development of certain cognitive structures and skills. Obviously, a certain degree of mental functioning is required for successful route selection. For example, Bowen and colleagues (1972) found that many patients afflicted with Parkinsonism:

... perform significantly below the level of normal controls on an established test of spatial orientation: namely, walking a route guided by a visual map. (p. 358).

It may be objected that a map-following test is not necessarily a test of route-finding ability. Garling (1975) observed that maps and other forms of "intellectual" knowledge are aids which may be useful but are not required by the route-finder:

Possibly, the information from maps as well as acquired spatial representations of route systems enable the individuals to determine their position during movement which in turn may have effects on confidence, the possibility of correcting wrong choices, and to effectively choose unknown paths. This orientation with the aid of intellectual knowledge ... is seen as an aid to navigation and route-finding, though not always necessary for successful performance in a more restricted sense. (p. 175).
Further, Piaget and Inhelder's (1956) research on the development of spatial concepts in humans is consistent with the idea that the basic spatial abilities needed for route-finding are well-developed at an early age. Thus, with some exceptions, it seems reasonable to assume that most adults possess the basic cognitive equipment necessary to navigate successfully in the urban environment. Maps may be seen as important aids in route-finding once the basic cognitive skills have been developed and sharpened.

From a cognitive perspective, one of the most important "maps" is the individual's "mental map" or "cognitive schema". The mental mapping perspective holds that each individual has some sort of "representation" of his/her spatial environment stored within the memory. This "cognitive schema" of the environment is "consulted" when the individual wants to go somewhere or find a particular place. There is debate concerning the precise manner in which spatial information is retained in memory, but most advocates agree that spatial information is stored in memory and that the nature of this information has an influence on subsequent behavior by the individual in space. Still useful, general statements on mental mapping and spatial orientation include a brief essay by Lee (1969) and a book-length review by Howard and Templeton (1966). Lee noted the relevance of the "spatial schema" approach to geographical orientation. This avenue is further explored in Downs and Stea (1973). More recent, comprehensive discussion is found in Rapoport (1977, especially pp. 108-177).

There is a large literature which discusses "distortions" and
"gaps" occurring in the mental maps that individuals have of their environments. These issues presumably have ramifications for route choice. For example, if an individual does not know that a given route exists, then it is more likely that a more familiar, known route will be selected. Further, if a given route is perceived as quite lengthy (even though it may be relatively short in comparison to other possible routes) it may not be considered with much favor if the pedestrian wants to take "the shortest" route to a destination. Many factors appear to be responsible for such perceptual distortions. These include: travel experience, psychological fears, social status, mode of travel, and so forth.

Rapoport (1977) made an important distinction between experimentally perceived distance and remembered distance. Complexity (i.e., having more choice points and/or turns along a path) tends to increase the amount of information available along a given path. Since there is more information to process, such a route may seem longer. This depends on a temporal factor, however. Rapoport noted that the experience of the pedestrian at the time of travelling a route is that the route is shorter when the route is complex rather than simple. This results from having his interest held by the increase in usable information available on a complex trip. Thus, a trip which is complex seems more exciting and quickly completed. But, after the trip is over, the remembered trip seems longer than it did at the time he actually experienced it. He stated:
Experientially high information environments seem shorter to transverse than low information ones, but this is reversed in memory. Complex routes are experienced as short and remembered as long and vice versa. (p. 219).

The logic of the mental mapping approach is attractive, yet few studies have been able to show much behavioral connection between mental maps and the observed behavior of individuals in urban space. There is basically only one major study which has, so far, attempted to link pedestrians' route choices to the concept of mental maps. Because of the issues it raises, Marchand's (1974) investigation in Paris, France, is worthy of discussion.

Marchand obtained, from each of 246 subjects, "a detailed description of his itinerary when walking from home to the [subway] station" (p. 492). These itineraries represent a 12% questionnaire response, resulting in a sample which "is obviously biased" (p. 492). The individuality of each "itinerary" was lost, however, as a result of Marchand's cartographic approach. His mapped presentation of "routes" does not show individually identifiable paths. Rather, the data have been aggregated to produce what is essentially a flow diagram showing frequencies any given link in the street system was utilized by pedestrians. All information concerning the sequences of links which might have been combined into actual routes has been lost through aggregation into flows. Flow data are useful to engineers, but they provide little insight to students of route choice.

The aggregation of data into flows makes it difficult to fully
evaluate several assertions offered by Marchand. For example, he stated:

Pedestrians show clearly a tendency to follow the *simplest* path even if it is not the shortest. They walk first to the main straight axis, then follow it all the way to the station. (p. 504).

The definition of "simplest" is not clear. But, more crucially, the above cannot be determined from Marchand's map of aggregated routes or from any other data presented in the paper. If one assumes that the flows are, in fact, routes or itineraries, the data actually appear to largely support a shortest path hypothesis.

A further possibility for misinterpretation occurs in Marchand's observation that the graph theoretic interpretation of his aggregated map of itineraries does not allow it to be defined as a "tree" (cf., Deo, 1974, for a discussion of graph theory terms). He then argued that "this might appear as proof of some freedom of choice of itinerary" but then noted:

... for instance at the crossroad between Avenue Carnot and Avenue Gambetta each flow goes on straight ahead and crosses the other. (p. 504, Italics added).

The conceptualization of aggregated flows as "crossing" each other is a major mistake. They could, for example, just as easily be seen as "mixing" or "joining". Marchand is required to present far more detailed analysis of actual routes if his otherwise interesting ideas are to be salvaged.
Marchand also asked his respondents to draw a map of the neighborhood in which they lived and in which the studied subway station was located. On the assumption that distortions in these hand-drawn maps were related to distortions existing in the mental map of the subject, Marchand made a detailed analysis of the subjects' mental geometry of the neighborhood. This study is, in itself, interesting and relevant to the growing literature on mental maps. A problem occurs when Marchand attempted to link the aggregated mental map data to the aggregated itinerary or route choice data. The most that can be said is that the linkage is highly tenuous. The aggregations performed by Marchand leave the analysis open for artefactual interpretations and leave the reader somewhat skeptical of both the "theoretical laws of pedestrian behavior" (pp. 501-502) as well as the "observed laws of pedestrian behavior" (pp. 504-505) proffered by Marchand. This French study amply illustrates the problems encountered in attempting to relate the mental mapping literature to the actual route choices made by pedestrians. It is hoped that Marchand's innovative first attempts will be followed by additional work which recognizes and preserves the integrity of individual pedestrian itineraries.

A related cognitive approach focuses on the interpretation of incoming percepts. Here it is assumed that the individual's cognitive schema acts as a "filter" through which immediate percepts must pass. There is very little prior work which bears directly on the case of urban pedestrians, but there are a few clues here and there. Relying almost entirely on concepts of immediate information processing, Best
(1970) examined orientation in large buildings. He found that the character of signage was an important variable in explaining "lostness". Braaksma (1980) proposes a "sight line" approach for reducing orientation problems in large air terminals:

\[ \ldots \text{based on the premise that human orientation is a function of the visibility of the destination that the person is moving towards. (p. 201).} \]

For the urban pedestrian, the "destination" is not always in view at the start of the trip. Clearly, however, one must be able to interpret incoming, visible messages if one is going to use them in the process of route-finding. Studies on the interpretability of maps have also been completed (e.g., Bronzaft, Dobrow, and O'Hanlon, 1976; Garland, Haynes, and Grubb, 1979) for transit systems, but not for users of the pedestrian mode per se.

The whole question of visual cues is still fairly open and the studies noted above only begin to scratch the surface of this important topic. Despite the lack of a solid base of data, it does appear, however, that a few, basic things could be done in the urban environment to make it more easily interpretable. For example, Woodson (1978) pointed out that:

\[ \text{In most cities street signs are typically placed on only one corner. The signs are too high for the partially sighted to read, and obviously the blind have no way to identify the streets. (p. 542).} \]

The specific needs of the blind raise several additional questions which are still under investigation.
For the blind, visual cues available to sighted pedestrians are irrelevant. Thus, it can be assumed that the role of the blind person's cognitive map becomes more crucial as does the provision of environmental cues which use sensory channels other than sight. Little is known about the route-finding experiences of blind pedestrians, although Woodson (1978) provides an introduction. A behavioristic approach to this topic has been proposed by Schingledecker and Foulke (1978). Although they note that:

> Because pedestrian performance is complicated, any methodology for assessing performance of blind pedestrians must be constructed with special care. (p. 275)

they conclude that an "objective" approach is preferable. How unfortunate, because "objective" measures of observable "performance" tap such a small aspect of the pedestrian experience, especially for the blind.

Many pedestrians may experience the pedestrian environment as stressful and this is accentuated in the case of blind pedestrians. Wycherley and Nicklin (1970) found that the heart rate of blind pedestrians was significantly higher than that of sighted pedestrians who walked a 0.6 mile route in a housing estate on the outskirts of Nottingham, United Kingdom. They concluded:

> The data, therefore, indicate a substantial component of psychological stress, for blind pedestrians on a novel route, which declines with repetition. This appears to be specific to the route used. (p. 190).
In other words, blind pedestrians face new threats of stress each time they elect to find their way along a route which is novel to them. The origin of this stress is not known. It may be due to fear of becoming lost or fear of being struck by motor vehicles. The effort required to construct a new addition to one's inventory of mental maps may result in stress. These and other possible sources of stress remain uninvestigated at the present time. It is now known only that the sighted apparently experience less stress than the blind when exploring new routes as pedestrians.

Introduction to Route Finding Strategies: This study adopts another alternative to the gravity model approach. It is based on the language of *strategies*. This section introduces this framework and reviews those studies which have adopted this approach for the study of route choice by pedestrians. The strategy approach generally takes note of all of the other alternative approaches reviewed above. In general, the strategy approach assumes that most adults and many children possess adequate cognitive structures and social skills for navigation within an urban environment. Given these assumptions, the pedestrian is asked: What is your strategy for choosing routes?

Asking about route finding strategies seems an especially relevant question for visitors to a new city. Kobayashi (in press) developed a computer simulation approach which may eventually help provide answers or, at the least, helpful clues. Kobayashi builds a model which allows a stranger in a new city to choose a path. The
model is based on the assumption that:

... in an unfamiliar city, a visitor will take a simple route to get to his destination lest he go astray.

Hence, the visitor's assumed strategy is to keep the path "simple" in order to keep from getting lost or disoriented. During each run of the model, a simulated pedestrian is "sent" in search of destinations in a "city" in which street patterns, visual landmarks, and information points are manipulated by the programmer. This method provides an experimental system for suggesting where orientation points or "signboards" should be located to best help keep new visitors to a city from getting lost. This simulation approach allows the programmer to make various assumptions about different types of search strategies and to explore the results in a simulated environment.

Schneider (1975), in a well-argued theoretical paper, discussed several problems related to the route-choosing behavior of urban residents. He was first interested in trips which were primarily searches, those in which the individual is looking for something. Schneider considered two, basic types of searching. First, there is a "space-exhausting" search in which a person begins to:

... actively move through the city ... looking directly for the target by examining locations sequentially until one with the required traits is encountered. (p. 173).

Second, the pedestrian may engage in "route-finding search" wherein:
he/she may first seek information about the target, including an address, and then locate the target through actively seeking that address by route-finding search. (p. 173).

Further, in the route-finding search, it is assumed:

... that the searcher, through careful use of maps and other information sources, selects the shortest path between his/her point of origin and the nearest target, and that during the journey the person does not become lost or confused, thus increasing this distance. (p. 174).

Schneider suggested that space-exhausting search "works" only when the relative density of the desired targets is fairly high. He observed that:

... few targets have the densities required for location by simple space-exhausting search. Mailboxes, taverns, and small groceries may achieve these densities. (p. 183).

On the other hand, many desired targets in urban areas are not randomly located, but have a patterned structure so that their presence is more likely or "expected" by the searcher to be found in some areas rather than others. For example, mailboxes are often found near major street intersections. Further:

In all cases approximating space-exhausting search, exogenous information is utilized so that the actual search pattern, even when undertaken in a totally unfamiliar neighborhood, reflects spatial inhomogeneities familiar to urbanites. ... In looking for a grocery store, for example, the searcher will probably concentrate on finding a busy street, where such activities will more frequently be located than on a
quieter street. In this way the individual's perception of regularities within the environment is used to reduce search distances, even though neither the path nor end point is familiar. That is, random patterns contain no information, but nonrandom patterns do (although, in an information-theoretic sense, essentially the opposite may be argued), and the information in nonrandom patterns is used by searchers to reduce their expected search distance. (p. 180).

The above reference to "patterned" structures echos an essay by J.B. Jackson (1957) in which he described the "path" taken by new arrivals in American cities. In most cases, Jackson found the morphology of this path, composed of bus stations, flop houses, pawn shops, rough taverns, etc., to be repeated in city after city. The stranger in a city, Jackson argued, knew where he could find a whole range of desired services and activities regardless of which city he might find himself in. Jackson's "path" illustrates the kind of exogenous patterning to which Schneider points as central to more efficient searching strategies.

Schneider also noted the importance of signs in locating points and proposed that signs with differing configurations and degrees of visibility would result in variations in average search distances. Two factors were assumed to influence the distance at which a subject could detect a sign:

(1) the lettering on the sign decreases in interpretability with distance and,
(2) more important in urban areas, is the blocking or masking effect of other signs along the pathway. In a heavily commercial area, the extent to which signs interfere with each other at any appreciable distance is quite great. (p. 179).
Observations such as these demonstrate that questions concerning search strategy overlap with issues central to environmental perception specifically and the cognitive approach generally.

In any event, given that a point in space must be located, does a pedestrian select route-finding search or space-exhausting search? Schneider discovered that all models of space-exhausting search:

... require from two to fifty times as much travel as successful route-finding for targets whose expected distances are up to one mile. Moreover, as expected distance to the nearest target increases, this ratio becomes still more unfavorable. (p. 183).

Thus, it could be assumed that adult pedestrians have learned how "expensive" it is to conduct a space-exhausting search. As an alternative, they would likely pursue a route-finding search with all that it implies about careful use of maps, addresses, and other locational aids. Even if this careful preparation is not possible, it can be assumed that the astute pedestrian utilizes his/her knowledge of the non-random nature of urban form to at least delimit a small area in which to concentrate a space-exhausting search. Several studies noted above revealed that pedestrians often report taking the "shortest route". If so, they probably know where they want to go and how to get there before starting out. If they do not, it can be assumed that they do their best to delimit a small area of likely search, head toward it while inspecting signs, look up and down streets at intersections, and use other cues in order to come close to a shortest route solution. This latter hypothesis assumes considerable search
sophistication on the part of the average pedestrian. The frequency of this type of search is unknown. Schneider's paper presents only a theoretical discussion of search strategies rather than an empirically grounded investigation.

Regardless of search strategy employed, it can be assumed that most pedestrians either take shortest route paths or attempt to approximate shortest route paths through the careful use of environmental cues. Prior research by this author (Hill, 1978a) indicates a high occurrence of shortest distance path taking by observed pedestrians. A finding that pedestrians take shortest routes is interesting but hardly exhausts the questions which can be posed in an urban environment characterized by a grid-like street pattern, a situation which occurs in most American cities. In a grid system, there are several routes to many points which are all "shortest". This observation, detailed below in considerably greater detail, brings the reader to the focus of the present study: What strategy does a pedestrian utilize in order to select from among several, equally attractive, equally short alternative routes to a destination?

A Strategy Framework for Route Choice

This study proposes a conceptual extension of previous work by another scholar. Thinking about pedestrian behavior as a game played on a graph builds on earlier efforts by Dietrich Garbrecht (1969, 1970, 1971b). It extends, from a strategy-oriented perspective, his innovative theoretical work on pedestrian path selection within an
environmentally uniform rectangular grid. It is important to note that Garbrecht's theoretical models remain untested empirically except for a small pilot study completed by this author (Hill, 1978a). Thus, one aim of this study is to give a more full-fledged empirical grounding to this line of thought. The emphasis given to Garbrecht's work in framing this study is due in large part to the fact that his efforts represent one of the few alternatives to a gravity model perspective on pedestrian path selection, a point underscored by Pushkarev and Zupan (1975). This investigation attempts a strategy-oriented extension of existing ideas about route-choice and makes possible an indirect test of previously proposed but untested models of pedestrian path selection.

Realization of this study's objective requires correspondence between the proposed conceptual framework on the one hand and a concrete, empirical situation on the other. It is argued here that a graphic representation of the strategy employed in an observed trip through an urban area is congruent with the pedestrian's decision strategy for completing a given trip. This assumption is central to the logic of this study. The basic problem is that a decision-making strategy is internal to the individual. Thus, some way must be found to externalize it before it is possible to evaluate it.

Cooper and Elithorn (1973) maintained that (in many instances) observable, external behaviors are intrinsic parts of a problem-solving process such that the pattern of these behaviors provides clues about the internal problem-solving activity and also provide "a physical set
of markers which form a track through the problem space" (pp. 199-200). This rationale led them to select boardgames like chess and checkers for the study of internal processes. Thus:

In choosing a boardgame to study thinking, we have been influenced considerably by the opportunity that this offers to record operations by the subject on a mechanical system which is part of the problem structure. Since the problem requires the subject to make a series of sequential choices from subsets of possible moves we can use an analysis of the subsets and the choices he makes from them to test hypotheses about his thinking processes. Moreover as these externalized responses are an integral part of the problem it cannot be argued that recording them objectively will interfere with the internal aspects of the problem solving activity. (p. 200).

Based on the logic of the argument by Cooper and Elithorn, it is argued here that pedestrian route selection is, in fact, a big-as-life game played on a city-wide gameboard and that this situation can be exploited successfully for the study of decision strategies used in human way-finding, at least in an introductory way.

The conceptual viewpoint adopted for the present study characterizes the pedestrian trip as a game. In the most general game, "winning" consists in successfully reaching a destination from a stated origin. More complex and sophisticated games (e.g., journey-to-work, going shopping, visiting a friend, finding an address, getting some exercise, etc.) can be contemplated and distinguished on the basis of rules of play and criteria for winning. Research on pedestrian walking speeds and acceptable walking distances suggests that the criteria for winning many of the most general pedestrian
games are a function of spatial and/or temporal minimization, i.e., that trips should be short in both distance and time. Other possibilities will be suggested below.

It should be pointed out that game theory per se has come under criticism within geography by Richard Prentice (1975), who maintained that formal game theory requires unjustified assumptions and fails to completely model decision-making processes. Even if Prentice's argument is accepted as valid, his critique does not exhaust the concept of "game" per se. The ordinary language concept of game is associated with a rich family of related notions (e.g., winning, losing, goal, strategy, playing field, gameboard, penalty, rules, sportspersonship, referee, spectators, players, etc.) useful in the conceptualization of pedestrian behavior. The concept "game" has no unitary definition in ordinary language. This was specifically observed by Wittgenstein (1953) in relation to language games:

... the result of this examination is: we see a complicated network of similarities overlapping and criss-crossing: sometimes overall similarities, sometimes similarities of detail.

I can think of no better expression to characterize these similarities than "family resemblances"; for the various resemblances between members of a family: build, features, colour of eyes, gait, temperament, etc. etc. overlap and criss-cross in the same way. And I shall say: 'games' form a family. (p. 32).

This helps to underscore the point that formal concepts of game theory do not exhaust the concept of "game" itself. There are other members of the "family" which can be invited for discussion when the more
formal branch of the family proves stubborn and uncooperative. For example, there is Suits' (1967) conclusion that:

\[\ldots\text{to play a game is to engage in activity directed toward bringing about a specific state of affairs, using only means permitted by specific rules, where the means permitted by the rules are more limited in scope than they would be in the absence of the rules, and where the sole reason for accepting such limitation is to make possible such activity. (p. 156).}\]

With this conceptualization of a game, one needs only to posit that the specific state of affairs to be brought about is that of successfully reaching a destination and to observe that pedestrian behavior in urban areas appears to be governed by at least a minimal set of social norms to conclude that much pedestrian behavior may be legitimately characterized as a game.

The urban environment in which pedestrian games are played is conceptualized as a graph. Streets are identified as edges, intersections become vertices, and the route selection process is conceived as the linking of an origin and a destination via selection of edges in a network to form a walk which may be either open or closed. Such a graph incorporates several salient structural elements of an urban path system and can be viewed as the gameboard for the play of various pedestrian games.

The play of pedestrian games on highly structured spatial gameboards is especially characteristic in urban environments. The spatial structure of the city is a limiting environmental constraint which does not characterize open field situations such as those
studied by Menzel (1973) who observed the search behavior of chimpan­zees in a spatially open environment. Under the conceptualization of the pedestrian environment as a graph, the problem of route selection from a set of pre-existing edges is a human-made problem. It is im­posed upon the pedestrian by the structural form of the human-built environment through which he/she travels. Thus, the structural aspects of the urban environment are not presented as influences on the behavior of the pedestrian, but as spatial problems which require solution and negotiation in everyday life. By focusing on the decision problem of choosing between alternate routes of equal length, this study does not focus on space or distance as a causal variable. Instead, it is the physical structure of urban space as a medium for behavior which is given primary emphasis.

To summarize: completing a walk requires the sequential selec­tion of edges from those available in a graph. It is in this regard that pedestrian route selection resembles a game, since in game theory a game may be defined as a sequence of decisions. The decision-making aspect of a pedestrian game can be seen as a tree where each vertice represents a decision point. Thus, any sequence of moves is a series of choices, one after the other, which continues until the game is over. A planned sequence of such moves is called a strategy. The comparison of observed strategies with those consistent with various theoretically postulated strategies provides the empirical-theoretical linkage and focus for this study.
Hypothesized Spatial Strategies

The term "complexity" is a fundamental concept in several of the discussions which follow below. This term refers to the extent to which a pedestrian structures a route such that more turns (i.e., left or right) are effected than would be necessary if a less complex or "simple" path were chosen. Thus, a "simple" route is one with the bare minimum of turns and a complex path is one with as many turns as possible. Empirically, there is the possibility of selecting a route with a number of turns which lies somewhere between the minimum and the maximum possible.

Distance Minimization Strategy

It is the basic starting point of this study that the primary decision strategy used by pedestrians is selection of a route which minimizes distance. In a pilot study of 45 walking trips, it was found that in every case the observed pedestrian took a least distance path from the point of origin to the destination. Thus, if the pedestrian is faced with only one least distance path, it is assumed that this is the one which will be selected. It is in this sense that the distance minimization strategy is called a primary strategy.

However, it is somewhat more interesting to consider the nature of the pedestrian's choice when faced with choosing between two or more routes of equal length which all lead to the desired destination. This is a common situation in urban areas with a rectangular street
pattern. For example, a pedestrian who makes a trip to a diagonally opposite destination from an origin in a two by three block street grid (making the trip itself five blocks long) can take any one of ten possible routes of equal length to reach the desired destination. Thus, several secondary strategies for choosing between routes of equal length can be advanced. The following proposals emphasize the spatial structure of a range of choices in the urban environment.

**Complexity Reducing Strategies**

Marchand (1974) offered the conjecture that the pedestrian walks directly to the main perceptual axis and then follows it straight ahead, even if it is not the shortest path. Although deviations from shortest path routes have not been corroborated by North American data, Marchand's work is still interesting in that his hypothesis is consistent with the idea that the pedestrian is trying to reduce the number of critical decisions which must be made while walking. Thus, one strategy for choosing a route could be to choose one with few turns, one which is easy to remember and to follow.

**Complexity Maximising Strategies**

Other pedestrians may intentionally choose more complex routes, ones with many turns in them. Rapoport and Hawkes (1970) noted that the greater the number of turns in a route, the greater the amount of significant information available to the pedestrian. Thus, someone who is searching the grid network en route to a destination could be
expected to take a turning, twisting route in order to gain the maximum amount of environmental information available. The pedestrian would take a complex route with many turns in it.

Bussard (1977) suggested that considerable route complexity might result in urban districts where traffic flow is controlled by automatic traffic signals. Here, a pedestrian who wanted to minimize travel time might always cross the street at the first available "green light". Bussard proposed that the result would be a zig-zag route with several turns in it. In this case, the resulting complexity would not be intentional (as in information search, above) but an artefactual result of the timing of traffic signals.

**Strategies of Intermediate Complexity**

While there may be some pedestrians who always take "simple" routes as well as others who always take "complex" ones, it may also be proposed that many pedestrians take routes with intermediate levels of complexity. Two such strategies, first introduced by Dietrich Garbrecht, are outlined below.

**Random Walk Strategy:** A pedestrian who adopts this strategy makes a random choice at each intersection about which street to follow next. If these decisions are randomly distributed, the pedestrian would sometimes take a "simple" route along the outer edge of the grid. At other times, the route would be somewhat more "complex".

**Random Path Selection Strategy:** Randomness also plays a role in this
strategy, but the temporal location of the pedestrian's decision-making is different than in the random walk strategy identified above. It is assumed here that the pedestrian pre-plans the complete trip at the start, not as he/she walks along. At the start of the trip, the pedestrian chooses one of the several complete paths available and then follows it without deviation. On a subsequent trip, another route would be chosen randomly and it too, once chosen, would be followed without deviation until the destination was reached.

Since randomness plays such a central role in the presentation of both strategies of intermediate complexity, it might be thought that they are essentially identical. However, non-square rectangular grids offer an artificial situation in which the two strategies sketched above have observable differences. Garbrecht demonstrated that, in a rectangular grid, the random walk strategy and the random path selection strategy result in different expected frequencies of pedestrian flow over the same links in the grid network. The present author (Hill, 1978a) extended this argument by showing that the two strategies of path selection could also be distinguished on the basis of the frequency of paths taken with specified numbers of turns. For example, Table 1-1 shows these expected frequencies calculated for a sample of twenty-two hypothetical pedestrians.
Table 1-1: Expected Frequency of Trips with "X" Number of Turns

<table>
<thead>
<tr>
<th>Number of Turns in Path (X)</th>
<th>Random Path: Expected Times Path with X Turns is Chosen</th>
<th>Random Walk: Expected Times Path with X Turns is Chosen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.4</td>
<td>8.250</td>
</tr>
<tr>
<td>2</td>
<td>6.6</td>
<td>5.500</td>
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<tr>
<td>3</td>
<td>8.8</td>
<td>6.875</td>
</tr>
<tr>
<td>4</td>
<td>2.2</td>
<td>1.372</td>
</tr>
</tbody>
</table>

Example expected frequencies under two strategy assumptions for a hypothetical group of twenty-two pedestrians travelling from a lower left-hand origin to an upper right-hand destination in a 2 x 3 grid.

In summary, rationales have been provided for a range of route choosing behaviors. Complexity minimization would result in frequent choice of paths with very few turns in them. Information gathering, on the other hand, is expected to result in turn maximization. Two intermediate strategies were also introduced. Random walk tends to emphasize less complex paths and is characterized by pedestrians making changes in their route as they walk along. Random path selection is characterized by pedestrians who choose the structure of their entire route before they start their trip.

**Cognitive Strategies vs. Observed Strategies**

It is hypothesized that cognitive route structures, as revealed in "asking directions" interviews, will be less complex than the structure of routes pedestrians are actually observed to take when they walk from one place to another. Giving directions to a
stranger who asks how to find a given location is probably not fully equivalent to the cognitive processes which precede (and unfold during) an individual's own route choosing activity. Nonetheless, both processes (giving directions and choosing routes) require familiarity with the spatial organization of the local environment as well as the ability to fruitfully employ such information. Providing "simple" directions to a stranger reduces interaction time between the person asking for directions and the person giving the directions. This is consistent with Milgram's (1970) hypothesis that urbanites generally attempt to reduce the frequency and duration of interpersonal contacts with strangers. Further, giving "simple" directions probably increases the likelihood that the instructions are understood and remembered.

Thus, pedestrians are here conceptualized as cognitively able to reduce the spatial "complexity" of their environment (evidenced by giving "simple" directions). Yet, it is hypothesized that pedestrians take somewhat more "complex" routes when actually going for a walk themselves. This finding would be in accord with Rapoport and Hawkes (1970) who proposed that pedestrians probably enjoy having more than a minimal level of "complexity" in their trips.

**Variations in Trip Strategy by Age:**

It is hypothesized that children walking home from school will tend to have more complex path structures than adults generally. This proposal is based on Robert White's thesis of *effectance* in which it is maintained that:
... exploration, manipulation, locomotion, language and the practice of motor skills, the growth of cognition, the development of plans and intentional actions, and the emergence of higher thought patterns ... (cited in Perin, 1970, p. 46)

form the "growth processes" which, when put together, result in "man's complex repertory of adaptive behavior". Piaget and Inhelder (1956), together with Merleau-Ponty (1963), also presented arguments which support a general effectance model of environmental manipulation. In capsule form, such a model asserts that environmental manipulation is required during the development of the individual in order for the person to develop a sense of personal competence (cf., White), a sense of space (cf., Piaget and Inhelder), and a stable orientation in the world (cf., Merleau-Ponty). Thus, it is reasoned that school children will tend to be more exploratory in their route selection since they are still learning how to manipulate or navigate within the urban environment) than will adults generally. Using Rapoport and Hawkes as a guide, it is assumed that "exploratory" behavior will tend toward route choices with the maximum number of turns.

Variation in Trip Strategy by Gender

It is hypothesized that adult women may have slightly less complex trip strategies than adult men. This thesis is based on the observation by Beck and Wood (1976) that women are less able cognitive mappers than men. They suggest that this situation may have arisen from the fact that women in American culture are often passive passen-
gers when travelling and thus do not have a direct motivation to learn the routes over which they travel. If Beck and Wood are correct in their conjecture, then there should be no very great difference between women and men who walk as a usual mode of travel since there is no sense in which an individual female who is walking can be considered a "passive passenger". Yet, since it is possible that there might be some carry over from previous deprivation in practice in learning environments, it is hypothesized that women may show a slight tendency to take less complex routes than men. The rationale for taking a less complex route is that such a route is more easily conceptualized and remembered, thus reducing the risk of becoming "lost" while en route on the part of someone who is somewhat less experienced with the environment or who is unsure of his/her route-following ability.

Summary

This section outlined the major hypotheses in the present study and attempted to place the study well within the context of previous research on the behavior and experiences of pedestrians. A hierarchical model of walking skills was presented, working upward from "basic walking" through "crossing streets" up to "choosing routes". In this study, pedestrians are generally assumed to have mastered the basic skills, but do differ to some degree in their strategies for choosing among alternative routes when they are faced with more than one shortest path possibility. This study looks only at a fairly abstract
aspect of routes: the geometry of their spatial structure. Obviously, there are many more aspects of the pedestrian experience to be studied as noted in the review above, but these remain for other researchers and other times. In this study, the complexity of several spatial strategies is contemplated and discussed in the context of empirically collected data on actual route choices. The methods employed to collect these data are discussed more fully in the next chapter.
CHAPTER TWO

SAMPLING AND DATA COLLECTION

Introduction

This chapter outlines the procedures employed to obtain data and sampling points relevant to the questions posed above. Both temporal and spatial sampling techniques were required due to the clear impossibility for a single researcher to observe, track, and interview all of the pedestrians on the street at one time in a city of 180,000 people. Data collection procedures were selected to provide information on: (1) average levels of pedestrian flow within the study area, (2) the spatial structure of routes actually chosen by pedestrians as they walked from one place to another, (3) the ability of pedestrians to recall the spatial structure of routes they had been observed to follow, (4) the accuracy and spatial structure of routes given to a stranger asking for directions, and (5) the spatial structure of routes selected by a special sub-population of pedestrians:
grade-school children walking home from school. When appropriate, information was also collected on land use, temperature, day of week, time and duration of observations, location of observations, subject's gender and estimated age. The methods detailed here were selected in part because they permit cross-checking (or "triangulation") between data collection techniques. Each procedure reveals a somewhat different but related part of reality. Data were, therefore, collected in three primary modes: (1) ethological observation, (2) mail-in questionnaires, and (3) disguised interviews. A brief introduction to the study site is provided below, followed, in turn, by a description of the quadrat and point sampling methods and a summary of each of the primary data collection techniques utilized in this study.

The Study Site

Lincoln, Nebraska, was selected as the study site for this research project. Lincoln provides a diverse urban environment of moderate size (estimated 1978 population: 180,000). Within the general study site, a specific study area was delimited. This was defined as the contiguous, built-up area of Lincoln. This delimitation was accomplished using the U. S. Geological Survey 7.5 minute series (1:24,000) topographic quadranges for Lincoln and Walton, Nebraska, which employ color tints to indicate built-up areas. The contiguous, built-up area was traced from these maps and the resulting outline of the study area is shown in Figure 2-1. The Geological Survey maps were photorevised in 1972, thus reflecting conditions
approximately six years prior to the start of the present study.

The following characteristics describe the study area delimited by the above method: (1) it is probably a slightly conservative estimate of the built-up area, given the date of photorevision, (2) it has an interconnecting route network of streets and, in many cases, sidewalks, and (3) the area provides a wide range of environmental diversity. The following environments are represented: (a) commercial area (central business district, outlying shopping centers, and highway strip developments), (b) a few, small industrial and warehouse areas, (c) residential areas (both inner city and suburban), and (d) public and semi-public areas (schools, hospitals, government buildings, and parks).

The character of the street network in the study area is also representative of most forms found in the typical American city. The street pattern is characterized by a regular, rectangular grid alignment (or "Manhattan plan") in and around the central business district. Outward from the CBD, a few diagonal streets and boulevards provide discernable breaks in the basic rectangular pattern. Recently constructed suburban tracts are found near the outer edge of the city. These suburbs are often characterized by winding, curving road and sidewalk patterns which are the antithesis of uniform, rectangular grids. A sampling design was devised to capture this environmental diversity and varied street geometry in a representative manner.
Selection of Sampling Points

Two types of sampling points were utilized in this study: (1) street intersections randomly selected from sample quadrats within the study area and (2) randomly selected elementary schools. The process followed for selecting these sampling points is outlined below.

Street Intersections within Quadrats

Street intersections, where ethological observations began and disguised interviews were conducted, were randomly selected from sample quadrats within the study area. Choosing intersections from within spatially stratified quadrats helped to insure that a range of representative environmental situations would be tapped while also grouping or clustering the street intersections to some degree. The clustering of intersections served to reduce the researcher's travel time between observations and interviews.

Quadrat Selection

A grid overlay was used to choose quadrats. This device was designed to insure that the initial selection of quadrats would be areally stratified and thus representative of the built-up environments and street patterns in the study site. This simple device was a large sheet of drawing paper, 24 by 36 inches, on which a large grid was drawn with 2 by 2 inch cells. Each large cell was subdivided into four smaller cells, each 1 by 1 inch square. Each of these smaller
cells represents 400,000 square feet or approximately 0.14 square mile. A portion of the "quadrat selection grid is reproduced in Figure 2-2.

The quadrat selection grid was randomly overlayed on the Lincoln and Walton quadrangle sheets. Within each of the larger 2 by 2 inch cells, one of the smaller 1 by 1 inch squares was randomly selected and examined. If the selected cell included at least a small portion of the contiguous, built-up area of Lincoln, the small square (or quadrat) was included in the initial quadrat selection pool. In all, 32 quadrats qualified for inclusion in the initial pool.

In order to minimize the number of general localities that would have to be visited during data collection, 20 quadrats were selected from the initial set of 32 quadrats. The criterion used in choosing the final set of 20 quadrats was the rule that the quadrats with the most dense route networks should be retained. This criterion is justified on the basis that the study is primarily concerned with route selection in characteristically urban areas, i.e., where there are many streets and intersections per unit area. Initially, it was hoped that one of the several graph theoretic measures such as the cyclomatic number, alpha index, beta index or gamma index (cf., Tinkler, 1977) might provide an objective guide for selecting the final 20 quadrats from the original pool of 32. However, since each of the street networks in each quadrat was only a sample of a larger network (and because the quadrat boundaries were arbitrary and had, in themselves, no theoretically grounded meaning), there were
Figure 2-2: Example Portion of the Quadrat Selection Grid
definitional difficulties in determining how the graph representing the street network in each quadrat should be "closed" so that the needed indices could be computed.

Given this closure problem, it was decided to use a simpler index of route density: density of the street network estimated by simply counting the number of street intersections within each quadrat. Previous research (cf., Haggett, 1966, pp. 73-74) has shown that intersection density is highly correlated with street density in urban areas. Thus, intersection density was used here as an approximation of network density. The 20 quadrats with the largest numbers of intersections were selected for the final set of quadrats. The 1 by 1 inch quadrat with the lowest number of intersections possessed a total of 16 and the quadrat with the largest number of intersections was found to have 34 intersections. The mean number of intersections per quadrat was 24. The number of intersections in each quadrat are reported in Table 2-1. The identification number assigned to each quadrat in Table 2-1 is the permanent identification key for reference purposes in this study. The spatial location of the final set of 20 quadrats is shown in Figure 2-3.

Selecting the 20 quadrats with the highest estimates of street density reduced the final set of quadrats to a representative sample of areas with relatively dense street networks. Given the aims of this research project, it was felt that these quadrats would provide the most interesting and useful data. On the other hand, the selection was somewhat biased against quadrats at the outer edge of the
Figure 2-3: Sample Quadrats with Identification Numbers
city as well as those which included large amounts of park or other
open land not serviced by streets.

<table>
<thead>
<tr>
<th>Quadrat Identification Number</th>
<th>Number of Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>27</td>
</tr>
<tr>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td>11</td>
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<tr>
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<td>13</td>
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</tr>
<tr>
<td>19</td>
<td>28</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Street Intersections as Interception Points

Intersections are the points where counts were made, trips were
intercepted and ethological observations began, and where disguised
interviews were completed. Five interception points were randomly
selected from the total number of intersections in each quadrat, giving a total sample of 100 interception points. The resulting sample points may be technically described as a stratified, clustered, random point sample. This form of sample has both drawbacks as well as advantages. Haggett (1966) suggested that the sampling efficiency of this technique is not especially high if one is interested in obtaining a representative point sample of an entire study area. However, it should be recalled that the initial stage of the sampling procedure called for obtaining a representative, stratified quadrat sample. The second stage problem was to obtain a set of randomly selected sample points within each of the representative quadrats. Further, even if the sampling procedure is construed as a stratified, clustered, random point sample rather than as a series of random point samples within previously selected quadrats, there is a very important rationale for making use of this technique in this case. The issue is one of weighing sampling efficiency against practical efficiency. By clustering the sample points on a quadrat by quadrat basis, it became possible for the researcher to concentrate study time on actual observations rather than have a considerable amount of time lost in extended travel to less compactly organized sample points. This is standard procedure in the conduct of social surveys where increased travel time would seriously impair the viability of the study (White, 1977). The specific location of each intersection selected is shown, grouped by quadrat, in the Appendix (pages 248-50).
Elementary Schools

Data were required on the spatial structures of routes chosen by elementary school children as they walked home from school. Observations of such trips must therefore begin at elementary schools, making it necessary to select a representative sample of such schools. There were 27 public elementary schools within the boundaries of the built-up area of the study site. Ten of these schools were randomly selected as interception points for the study of route-selection by young children. The locations of the selected schools are depicted in Figure 2-4-A. Each school was contacted by the researcher to verify the range of grades in each school. All were found to have afternoon classes in kindergarten through sixth grade. In addition, enrollment figures for each of the schools were obtained as well as the afternoon dismissal time. The schools selected had a maximum of 700 students enrolled and a minimum of 168. The mean number of enrolled students was 418 per school. The name, address, dismissal time, and enrollment data for each school are presented in Table 2-2.

Collection of Land-Use Data

Land-use composition was checked and summarized for each of the 20 sample quadrats. Unfortunately, the City of Lincoln does not publish detailed land-use maps. Exceptionally detailed maps are maintained by the Planning Department but these are not generally available for public use. The City does update a single 7 by 9 foot wall
SCHOOLS SELECTED AS ROUTE ORIGINS

Figure 2-4-A: Location of Selected Elementary Schools
### Table 2-2: Elementary Schools Selected as Observation Points

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Dismissal Time</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beattie</td>
<td>1901 Calvert</td>
<td>2:45 PM</td>
<td>380</td>
</tr>
<tr>
<td>Calvert</td>
<td>3709 S. 46th Street</td>
<td>3:15</td>
<td>700</td>
</tr>
<tr>
<td>Hartley</td>
<td>730 N. 33rd Street</td>
<td>3:00</td>
<td>292</td>
</tr>
<tr>
<td>Havelock</td>
<td>6224 Logan</td>
<td>2:50</td>
<td>185</td>
</tr>
<tr>
<td>Huntington</td>
<td>4601 Adams</td>
<td>3:00</td>
<td>475</td>
</tr>
<tr>
<td>McPhee</td>
<td>820 S. 15th Street</td>
<td>3:00</td>
<td>320</td>
</tr>
<tr>
<td>Meadow Lane</td>
<td>7200 Vine</td>
<td>3:00</td>
<td>683</td>
</tr>
<tr>
<td>Morely</td>
<td>6800 Monterey</td>
<td>2:40</td>
<td>643</td>
</tr>
<tr>
<td>Norwood</td>
<td>4710 N. 72nd Street</td>
<td>3:00</td>
<td>161</td>
</tr>
<tr>
<td>Riley</td>
<td>5021 Orchard</td>
<td>3:00</td>
<td>340</td>
</tr>
</tbody>
</table>
map which was photographed for use by this researcher. Land-use data were then transferred, parcel by parcel, to a 3 by 3 inch enlargement of each quadrat. The per cent of land in each quadrat coded in each general land-use category was then measured and tabulated. The results are displayed in Table 2-3. A generalized map of land-use within the study site is presented in Figure 2-4-B. This map also indicates the approximate location of the central business district (CBD).

The City Planning Department was unable to provide even a rough estimate of the per cent of land in Lincoln within each land-use category. The best estimate available was an out-of-date (1974) estimate of land in each zoning category. In short, the information available was badly dated, reflected zoned use rather than actual use, and was only available for the entire area within the city limits of Lincoln (an area much larger than that delimited for the study area). Thus, it remains difficult to make even a rough estimate as to the representativeness of the environmental diversity sampled in the 20 quadrats selected. Beyond this, however, it is important to note that the selected quadrats include a high per cent of residential use. This is significant because the vast majority of studies on pedestrian flow and movement have been sited within areas which are primarily commercial in character. This study becomes, therefore, the first large observational study of route selection across a representative range of urban environments: residential, commercial/industrial, public/semi-public, and park land.
Table 2-3: Land-Use in Sample Quadrats

<table>
<thead>
<tr>
<th>Quadrat Number</th>
<th>Residential (%)</th>
<th>Industrial/Commercial (%)</th>
<th>Public/Semi-Public (%)</th>
<th>Park (%)</th>
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<td>1</td>
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</table>

Sample as a whole: 77 10 10 3

Figure 2-4-B: Generalized Land-Use in Study Area

Source: City of Lincoln, 1977.
Pedestrian Counts

Pedestrian counts were conducted to provide base level information on the extent of pedestrian activity within the study area. Half-day counts of pedestrian traffic were completed within each of the sample quadrats. Counts were made for 30 minutes at each of the five intersections within each quadrat. Thus, a total of 150 minutes observation was completed within each quadrat. Total observation time for the study area as a whole was 50 hours. All observations were completed on weekdays between the hours of 8:00 am and 12:00 noon. The counts were completed during late summer, 1977, prior to the start of public and parochial school terms. Thus, the observation periods represent normal flow activity during relatively hot, late summer days.

The counts were completed by stationing a researcher at each interception point within a quadrat for a period of 30 minutes. The order in which each quadrat was selected for observation was randomly determined. Likewise, the order in which each intersection was observed within each quadrat was also randomly decided. It was desired that the observations be made as unobtrusively as possible. When feasible, the researcher remained in an automobile parked near the intersection and simply maintained a running tally of the pedestrians who walked through the intersection. When an automobile was not available, the researcher stood near the street intersection and assumed the role of someone waiting to be picked up by someone else. As aids in this deception, the researcher carried a briefcase,
pretended to read a newspaper, looked frequently up and down the street, and consulted a wrist watch. At no time did pedestrians appear to reverse their direction of travel in order to avoid walking by the researcher (and hence through the intersection).

It should be reported, however, that the researcher's "disguise" was not entirely successful. On one occasion, after the 30-minute observation had been completed, the researcher started walking toward a pre-arranged pick-up point but was stopped, about two blocks later, by a police officer in a patrol car. The officer asked why the researcher had been standing on the corner for so long. The nature of the research was explained to the officer. This explanation was fully accepted and the officer departed. A few moments later, the researcher was pursued by an automobile which was then driven up across the sidewalk, blocking the researcher's path. An irate man demanded to know why the researcher had been "watching" his house. When the researcher explained the study and pointed out that the police officer (who had been summoned by the young man) was satisfied, the offended man calmed down, said he thought the study was interesting, and parted amicably. This one lone case of reactivity appeared to be largely a case of "paranoia" on the part of an overly suspicious party. In no case were actual pedestrians, the focus of the observations, judged to appear suspicious of the observer.

The results of the counts are presented in Table 2-4. A flow map based on the data in Table 2-4 is presented in the following chapter, Figure 3-4. Simple counting of pedestrians is, undoubtedly,
Table 2-4: Observed Pedestrian Flow through Intersections by Quadrat

<table>
<thead>
<tr>
<th>Quadrat Number</th>
<th>Pedestrians per Hour*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
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<tr>
<td>4</td>
<td>355</td>
</tr>
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<td>5</td>
<td>1</td>
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<td>6</td>
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<td>18</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
</tr>
</tbody>
</table>

*Per hour flow computed from 2½ hours of observation for each quadrat. All values rounded to the nearest whole number.
one of the least problematic forms of ethological study of pedestrians. Basic, as well as more sophisticated, methods are more fully discussed in Emmons (1965) and Mellor (1976).

Ethological Observation of Route Choices

This study employed ethological observation of intercepted pedestrian trips as a data gathering technique. Ethology is the comparative study of animal behavior (Tinbergen, 1969) and has long concerned itself with natural observation and the movement of animals as they migrate from one place to another, establish territories, and relate spatially to one another in groups. The non-intrusive approaches developed in ethology for observing movement have been adapted recently to the study of human behavior.

Unobtrusive observation of the route taken by a pedestrian is called "tracking" in the ethology literature. Tracking is a form of "simple observation", according to Webb and his colleagues (1966), in which:

... the observer has no control over the behavior or sign in question, and plays an unobserved, and nonintrusive role in the research situation. (p. 112).

These authors continued by describing several studies in which the spatial location of humans has been unobtrusively observed. For example, the seating choices made by blacks and whites have been used as indices of attitudes toward segregation. Werner and Wapner (1953) measured the distance individuals walked under conditions of
perceived danger as an index of the degree of danger perceived. More
germande to the present study are those works which have specifically
employed tracking to study movement.

Tracking was first used to study pedestrian movement by Weiss and
Boutourline (1962) in research on human activity at a World's Fair.
Their data took the form of a trip "log" in which the observed move­
ment and locations were noted verbally together with a record of when
each movement event took place. Interestingly, Weiss and Boutourline
suggested that an intrusive observer does not affect the behavior of
the subject:

When we first began working with this technique a
few parties were followed without their knowing it,
to give us a way of deciding whether awareness of
the observer made a difference in where they went
or what they did. It seemed not to. Occasionally an
observer would be asked for orientation, but this
did not seem to affect where the parties went. (p. 30).

Weiss and Boutourline did not give this proposition an adequate test,
however. They observed a total of only 28 parties, so the "few"
groups they followed unobserved must have amounted to only a handful.
Additionally, Weiss and Boutourline followed "parties" or groups and
thus the possible effect of a known observer on a group versus an
individual remains uninvestigated. Finally, it must be added that a
World's Fair is an unusual situation which does not compare with
everyday pedestrian navigation through a familiar urban environment.

Bechtel's (1967) study of movement behavior in museums provides
a good indication of the possibility of "observer effect". Bechtel
found that museum visitors who knew they were taking part in an experimental study of movement behavior acted much differently than "natural" visitors in terms of floor area covered and, hence, the routes taken. Such observed differences between experimental and non-experimental situations have been called "guinea-pig effects". Webb and his colleagues (1966) cited this effect in the following quote from a study by Selltiz:

The measurement process used in the experiment may itself affect the outcome. If people feel that they are "guinea-pigs" being experimented with, or if they feel that they are being "tested" and must make a good impression, or if the method of data collection suggests responses or stimulates an interest the subject did not previously feel, the measuring process may distort the experimental results. (p. 13).

Recent studies of jaywalking behavior (e.g., Russell, et al., 1976; Hill and Roemer, 1977) indicate that human behavior changes when a person feels that he/she is under the watchful eye of an observer. Hence, the author concluded that if unbiased spatial structure data were to be collected, the process used must be as unobtrusive as possible.

An example of unobtrusive tracking procedures is found in Winkel and Sasanoff's (1966) study of visitor behavior in the Museum of History and Industry located in Seattle, Washington. The purpose of their data collection was to provide a base against which to test a photographic simulation study of visitor behavior in museums. In their study, the following guidelines were followed:
At all times the tracker attempted to remain inconspicuous. It was found that observation at an appropriate distance allowed the preservation of an anonymity consistent with careful data collecting. (p. 622).

Tracking, in the above study, involved the recording of the subject's movement by drawing a line corresponding to the observed movement of the subject on a plan or base map of the museum. A similar approach is adopted in this study.

The only other study known to this author in which tracking has been used in the direct observation of pedestrian behavior in the street is Hoel's (1968) research on pedestrian travel speeds in Pittsburgh. Unfortunately, the details of Hoel's methodology are not detailed in the published article. A related approach is found in the qualitative studies of walking by Goffman (1971) and Wolff (1973). These insightful studies (which are in many ways superior to ethological analysis due to the richness of data produced) did not, however, reflect on the possible reactivity of photographic recording devices or participant observers.

In summary, it would seem that unobtrusive, ethological tracking has the most face validity as an information-gathering technique for learning the exact routes taken by pedestrians in urban environments. Data provided in Chapter Three permit further evaluation of this assumption, however.
Tracking Procedure Adopted in This Study

The quadrat for the day's observations was randomly selected, as was the order in which interception points within the quadrat were visited to begin tracking. When the observer arrived at an interception point, he positioned himself so that he could observe the intersection as inconspicuously as possible. A stopwatch was then activated and a three-minute "clearing period" was timed. This time period device was employed to insure that subject selection was left completely to chance and was not observer biased. At the end of the three-minute period, the observer began tracking the first unaccompanied individual who either stepped into the street intersection or rounded a corner at the intersection. Modification was required for high volume intersections in quadrat 4 in the central business district. Here, one corner of the intersection was randomly selected and the subject was again selected according to the above rules with the exception that the observer only had to watch for the first eligible subject to round the corner of the selected corner or step into the street intersection from the curbing of the selected corner. This modification was required because it was largely impossible for the researcher to keep track of all the activity on all four corners of a busy intersection at the same time.

Certain classes of pedestrians were exempted from observation: (1) pedestrians who appeared to be members of a group of two or more pedestrians, (2) those who appeared to have a regular route to
follow as part of a job, e.g., mail carriers, police officers, paper carriers, etc., (3) those who had been previously observed as subjects, and (4) any who were known personally to the observer. The latter two restrictions were imposed to reduce the chance that the subject might "catch on" to the fact that he/she was being observed.

Data collection consisted primarily of observing and noting where each subject walked. A pilot study conducted by this researcher (Hill, 1978a) indicated that it is possible to make observations from as much as one to two blocks away and from the side of the street opposite to the one on which the subject is walking. In crowded conditions, the observer must move closer to the subject, but the crowd itself masks the presence of the observer. The research completed here reconfirms this researcher's initial finding that tracking can be accomplished unobtrusively on urban streets in the pedestrian mode.

A standard data recording form was used for noting all observed information. An example form is provided in Figure 2-5. The grid on the form was used simply as a rough guide for mapping where the subject walked. The quadrat number and form number were entered at the top of the form as well as the date, day of week, and the time the observation began. The researcher also indicated the subject's gender and estimated age. The location and time of observation completion were recorded as well as an indication of whether a questionnaire (to be discussed below) was given to the subject following completion of the observation. In addition, data on air temperature were added
Figure 2-5: Tracking Worksheet for Route Choice Observations

Survey Number ___________ Quadrat Number ___________
Intercept Number _______ Date _______________________
Time Start _____________ Subject's Gender ___________
Subject's Age: ( ) 21 & Under, ( ) 22-61, ( ) 62+

TRIP GRID

Time End _________________ Temperature ______________
Questionnaire: ( ) Subject Lost, ( ) Refused, ( ) Accepted
Location End ____________________________
to each record after checking the hourly temperature reports in the next day's newspaper. Temperature for the hour nearest the start of the observation was the value entered on the record. Data forms were carried in a plastic covered, fold-over clipboard which proved very useful in windy conditions and/or rain showers.

An important practical and theoretical issue is the problem of deciding when a given observation should be terminated. That is, when did a particular pedestrian "complete" a trip? This was determined pragmatically. Observation was terminated when the subject remained in one location for a period of ten minutes or longer. This is an arbitrary rule, but any decision that a destination has been reached is in some sense arbitrary. Adoption of a "ten-minute rule" had the practical consequence of allowing the researcher to complete many more observations in a given day than if, for example, a one-hour waiting period had been used.

The results of these observations will be fully presented and discussed in the following chapter. However, it is appropriate here to provide a general indication of the size and character of the observed sample. In all, 200 observations were completed (ten in each quadrat). There were eight observations initiated but terminated when subjects looked backwards more than once in the direction of the researcher. In these cases, it was suspected that the subject might have concluded that he/she was being followed or observed. Since such suspicion could easily affect route choice, the observations were terminated and discounted from further consideration in the study.
112 subjects (56%) were women while 88 subjects (44%) were men. The shortest trip observed was .03 mile whereas the longest was 2.5 miles. The average trip was approximately .35 mile, or just a little more than four city blocks.

These figures represent data on *intercepted* trips. During this part of the study, observations were made on only the final portions of trips. For this reason, questionnaire data were sought concerning the origins of each trip and the routes which subjects had followed prior to interception by the researcher. The only observational alternative for obtaining data on *complete* trips is to station the observer at potential starting places (or "generators") for pedestrian trips, e.g., homes, offices, department stores, churches, schools, etc. The observer must then wait until a pedestrian exits from the trip generator before starting an observation. While this method was used in this study to gather data on children walking home from school, this procedure makes enormous demands on the researcher's time and is not well-suited to the task of obtaining data from a sample intended to be representative of all pedestrians in a large urban area.

Considerable physical effort was required to complete 200 observations within a two-month period (July and August, 1978). Even though the researcher was in good physical shape and an avid jogger at the time, he found upon completion of the observations that he had bruised his feet to the point that he was required to refrain from walking for nearly two weeks. It is difficult to estimate the total
miles walked during the observations. At the least, it amounts to
double the distance observed since it was necessary to return to the
quadrat of origin following completion of an observation.

Observations of Elementary School Children

A total of 50 additional observations were made of the routes
selected by grade school children as they walked home from school.
These observations were completed during March, April, and May, 1978.
These are observations of "complete" trips since the researcher
stationed himself at a pedestrian generator (a randomly selected
elementary school) and tracked a pedestrian until the observation was
terminated using the ten-minute rule discussed above. These observa­
tions are far more "expensive" in that the observer generally must
make a long automobile trip to a selected school and then wait for
the opportunity to make one observation when the children are dis­
missed from classes.

Observations were begun when the first student crossed through
the intersection nearest the main entrance door to the school. Data
were recorded only for children who walked home unaccompanied. Since
large numbers of children tend to walk in groups, the above
constraint may have resulted in selecting children who were not
necessarily "typical" children.

Reactivity was judged to be minimal. There is a surprisingly
large number of adults and automobiles waiting for children at the end
of the day. Thus, the researcher was not concspicuous. Two
observations were discontinued when the researcher felt that he had been "spotted" by the child under observation.

Data were recorded in the same way and on the same forms (see Figure 2-5) as those for the general, city-wide observations discussed above. Of the 50 subjects observed, 19 (38%) were male and 31 (62%) were female. The shortest trip observed was .06 mile and the longest was .83 mile. The mean length of the observed trips was .36 mile.

**Questionnaire Study**

The research design included a questionnaire study which would supplement the ethological observations discussed above. Not only did the questionnaire allow collection of data concerning unobserved portions of subjects' trips, it also provided information about subjects which could not be deduced from direct observation alone.

**Questionnaire Preparation**

Questionnaires were prepared to provide answers to two important issues. First, since trips were intercepted after they had already begun, information on the starting point of the trip was desired. Second, the researcher was especially interested in the ability of subjects to remember the spatial structure of the walking trip they had just completed. The following materials were prepared.

**Information Folder**

An information folder, titled "Answers to Questions about the
Lincoln Pedestrian Study", was prepared to be handed to subjects after they had completed a walking trip. It was hoped that the information folder would dispel any suspicions about the researcher's intent. A copy of the folder, originally printed on light blue paper, is illustrated in Figures 2-6-A and 2-6-B.

Field Questionnaire

A brief questionnaire was developed which asked the necessary questions for the study as well as a few inquiries designed to provide some insight into the nature of the subjects' responses. In addition to questions about route origin and composition, the subject was asked to indicate age, trip purpose, knowledge of trip destination, "pleasantness" of the route selected, and reasons for selecting the chosen route. Earlier versions of the questionnaire were pre-tested for legibility and coherence with students in introductory geography courses. As a result of pre-tests, the space provided for describing routes was enlarged and changed in shape. Students who volunteered to complete test questionnaires were interviewed to determine if they had understood the intent of the questions posed. As a result of these discussions, minor changes in wording were effected. The questionnaire was printed on bright yellow paper following the advice of White (1977) that respondents tend to more frequently return those questionnaires which are printed on brightly colored papers. The questionnaire itself is illustrated in Figures 2-7-A through 2-7-D.
ANSWERS TO QUESTIONS ABOUT
THE LINCOLN PEDESTRIAN STUDY

Research Office:
Department of Geography
Avery Laboratory, Room 323
University of Nebraska
Lincoln, Nebraska 68588

Chief Researcher:
Michael Hill
472-2571
WHAT IS THE PURPOSE OF THE LINCOLN PEDESTRIAN STUDY?
To establish a factual data base on which to make thoughtful recommendations to city planners.

WHY IS THIS IMPORTANT?
All too often, decisions about the improvement of pedestrian facilities (such as better lighting at night, provision of drinking fountains, safer crosswalks, and so on) are made without any real facts. These decisions are often just guesses about what is needed. This study will help correct this situation.

IS WALKING ALL THAT IMPORTANT?
Yes! Nearly 10 per cent of all trips in urban areas are completed entirely by walking. Think of all the children who walk to school every day. In addition, nearly all trips, even those completed mainly by car, involve some walking. Walking is the most basic and fundamental means of transportation.

WHY IS WALKING IMPORTANT TO ME?
Walking is not only good for your health, it is a good way to conserve both energy and your pocketbook. In addition, the more people walk, the safer our streets become.

WHAT WILL BE DONE WITH THE RESULTS OF THIS STUDY?
The results of this study will be tabulated and forwarded to city planners and interested citizen groups and neighborhood associations. Information which might identify individual participants will not be made public.

WHO IS THE SPONSOR OF THIS STUDY?
This study is part of the graduate research program in the department of geography at the University of Nebraska. If you have questions about this study, contact: Dr. Robert Stoddard, Department of Geography, University of Nebraska, Lincoln, Nebraska 68588. Telephone: 472-3573.

WHY WERE YOU CHOSEN TO BE A PART OF THIS STUDY?
You have just completed a walking trip. That is why you have been selected to participate in this study. The accuracy of this study depends on having everyone so selected take time to complete the questions asked by the field interviewers.

HOW DO I KNOW THAT THE INTERVIEWER WHO CONTACTS ME IS REALLY CONNECTED WITH THIS STUDY?
You may have the interviewer wait outside your door while you call Dr. Stoddard at 472-3573 for verification. If Dr. Stoddard is not available, the secretary at the department of geography will be glad to help you at 472-2865.

CAN I GET A SUMMARY OF THE RESULTS OF THIS STUDY?
Yes, by writing to: Michael Hill, Department of Geography, University of Nebraska, Lincoln, Nebraska 68588. A summary of results will be available in August 1978.
Field Interview Questionnaire

WHY SHOULD I COMPLETE THIS QUESTIONNAIRE?

You have just completed a walking trip. That is why you have been selected to participate in this study. Your response as a citizen is needed to help establish a factual data base with which to make thoughtful and accurate recommendations about walking conditions in Lincoln. Other questions about the LINCOLN PEDESTRIAN STUDY are answered in the enclosed flyer.

HOW DO I RETURN THE COMPLETED QUESTIONNAIRE?

Just put the completed questionnaire in the postage paid envelope and drop it in the mail. Please return the questionnaire even if you do not answer all of the questions.
INSTRUCTIONS: Just check the right box, fill-in the blank, or write in the answer space. If you want assistance in completing this form, call the research office at 472-2571.

QUESTION ONE

Check your age category:

☐ 5 - 16  ☐ 42 - 51
☐ 17 - 21  ☐ 52 - 61
☐ 22 - 31  ☐ 62 or older
☐ 32 - 41

QUESTION TWO

You have just completed a walking trip. That is why you have been selected to participate in this study. Please check the box which best indicates the purpose of the walking trip you just completed:

☐ Exercise
☐ Shopping
☐ Visit Friends
☐ Going to Church
☐ Going to Work
☐ Coming Home from Work
☐ Going to School
☐ Other: ____________________________

(Please Explain)

QUESTION THREE

On the trip you just completed, from what location did you start walking?

(Address, building name, or nearest street intersection)

QUESTION FOUR

When you began this walking trip, how well did you know the location of your destination?

☐ I knew exactly how to get here.
☐ I was pretty sure, but I wasn't absolutely certain how to find this location.
☐ I only had a general idea where I was headed, but I knew what this building looked like and that helped me find my way here.
☐ I didn't have a good idea of how to get here, I had to look around to find this place.
☐ I just stopped here by accident, I didn't plan on coming here.
☐ I wasn't really going anywhere, I was just out for a walk.
QUESTION FIVE: Describe the street route you took to get from the start to the end of the walking trip that you just completed. Just pretend you are writing directions so that a friend visiting from another town could follow the route you took. You may not be able to remember exactly what your route was, but try to be as accurate as you can. It may be easiest to just draw a little map of your route. Be sure to indicate the names of the streets:

Answer space for description of your route
QUESTION SIX: Evaluate the route you just described as a place for walking:

- Very pleasant
- Somewhat pleasant
- Neither very pleasant nor very unpleasant
- Somewhat unpleasant
- Very unpleasant

QUESTION SEVEN: What things about the route you just described led you to give the answer that you gave to question six? Try to be specific:

Answer space

QUESTION EIGHT: Is there any reason you can think of which led you to take the particular route that you described in question five instead of some other route?

Answer space
Questionnaire Delivery

Each questionnaire was coded with a number which tied it to a particular ethological observation. When the trip had been observed to "end" using the 10-minute rule, the researcher approached the subject, identified himself, and requested the subject to complete and return a questionnaire. Introduction was aided by quickly presenting the subject with a small business-type card (Figure 2-8) which gave the researcher's name, affiliation, and telephone number. The subject was then handed: (1) the information folder, (2) the questionnaire, (3) a stamped, pre-addressed envelope, and (4) a sharpened pencil.

The appearance of the researcher can have a reactive effect when the researcher must interact with the subject. Although the degree of reactivity is not known in this particular case, a picture (Figure 2-9) illustrating the appearance of the researcher at the time of handing a questionnaire to a subject is included here for purposes of documentation. The researcher was dressed in light colors, attempted to approach subjects with a friendly smile, and wore a bright red name tag which bore the researcher's name and the legend: "LINCOLN PEDESTRIAN STUDY".

Each subject was urged to complete and return the questionnaire at their earliest convenience. 158 subjects were given questionnaires. 42 subjects either refused to accept a questionnaire or could not be located at the end of the 10-minute waiting period following the
Figure 2-8: Business-Type Card Used to Identify the Researcher

MICHAEL R. HILL
CHIEF RESEARCHER
LINCOLN PEDESTRIAN PROJECT

DEPARTMENT OF GEOGRAPHY  LINCOLN, NEBRASKA  68508
UNIVERSITY OF NEBRASKA-LINCOLN  PHONE 475-2571
Figure 2-9: Appearance of Researcher When Delivering Questionnaires
end of the observation. Of those who accepted questionnaires, 97 (61%) completed and returned them. More detailed discussion of these data is reserved for the following chapter.

**Disguised Interviews**

The final aspect of data collection involved obtaining 100 recordings of cognitive or mental representations of pedestrian trips while eliminating, as much as possible, the reactive dimensions of a questionnaire approach. These data were obtained by asking randomly selected pedestrians (10 in each quadrat) for directions to a "landmark" in or near the quadrat in which the pedestrian was intercepted. Those interviewed comprised a separate sample from those who were tracked and handed questionnaires. The landmark chosen for use was the nearest elementary school, since it was felt that the majority of residents in an area would have some familiarity with the location of such a large physical structure which is socially important to the community. A map of these "cognitive targets" illustrating their location and relationship to an associated quadrat is found in Figure 2-10.

The researcher was disguised as a photographer. This allowed the researcher to legitimately carry a "camera bag" in which a tape recorder was placed. The recorder was specially wired with a microphone in the shoulder strap of the bag and a convenient on/off switch hidden from sight on the bottom of the bag. The researcher approached
Figure 2-10: Location of Target Schools by Quadrat
unaccompanied subjects saying, for example, "Excuse me, I have an appointment at the Hartley Elementary School to take some pictures and I guess my friend left me off at the wrong corner. Could you please tell me how to get there from here?" At this point, the tape recorder was unobtrusively activated and the respondent's answer recorded. The subject was thanked and the researcher departed. When well out of the subject's earshot, the researcher re-activated the tape recorder and added information including the subject's gender and estimated age, time of the interview, and any additional information such as street names or geographic directions needed to make sense of the "answer" just provided by the subject. The interviews were completed on weekends during the summer of 1978. The effect of weekend (rather than weekday) data collection is discussed in the following chapter.

The researcher's "disguise" was judged effective. The personal appearance of the researcher during the interviews is illustrated in Figure 2-11. In one case, the researcher had to decline a subject's offer to get a car and drive the researcher to the target school six blocks away since the subject felt it was "too far to walk to". In two other cases, subjects ran back to their homes to get telephone books to look up the address of the school. If anything, the researcher was impressed with the high level of friendliness and cooperativeness exhibited by the great majority of subjects interviewed. The high degree of friendliness may be due, in part, to having conducted much of the research in residential neighborhoods rather than solely in commercial business districts.
Figure 2-11: The Researcher "Disguised" as a Photographer
Data Standardization

The route data obtained from ethological tracking, questionnaires, and disguised interviews was in "rough" form and required "cleaning up" before it could be utilized in the analyses presented in the following chapter. All routes had to be mapped at the same scale before they could be compared. The tracking notes indicated the routes taken by subjects, but these hurried records were not always to scale. Questionnaire responses to the request for a description were not standardized. Some respondents drew diagrams while others gave verbal descriptions of their routes. All of the routes described in the disguised interviews were in verbal form.

Thus, each record had to be reconstructed and drawn at a common scale. A base map (scale: 1:8,000) of Lincoln was used as a guide for reconstructing each trip. This time-consuming process resulted in 250 separate maps of ethologically tracked trips (including the special sub-sample of school children) and 100 separate maps of routes reconstructed from the disguised interview data. Each map was drawn to include all possible routes of equal or shorter length that the subject could have taken to his/her destination.

The route information provided by returned questionnaires was then added, when appropriate, to the maps above. This often resulted in more detailed maps as knowledge of a longer, "complete" route resulted in mapping many more alternative routes of equal or shorter length which could have been utilized by the subject in question.
This set of annotated maps thus indicate the route segments subjects were observed to have taken as well as the routes which subjects reported themselves as having taken.

Transcribing the route data to a common scale allowed the researcher to measure the length of each trip using a map measurer and to make other calculations discussed in the following chapter. An example of one of these maps is illustrated in Figure 2-12 which shows the route taken home from school by a young child. Route data as well as all other information relevant to each case were then coded and key-punched in machine readable form.

Summary

In brief, 200 general tracking observations were completed. In addition, 50 school children were also tracked. Of the 200 general population subjects, 97 returned completed questionnaires which had been handed to them at the end of the observation period. Questionnaires were not given to the observed school children. Finally, 100 disguised interviews were conducted with subjects who were asked directions to the nearest elementary school. All of the routes observed or reported were then individually mapped to scale on a total of 350 separate sheets.
Figure 2-12: Example Route Record (School Children Sample, Case: 30)

Subject: Female
Length: .83 mile
Duration: 28 minutes

Identifying names suppressed to increase confidentiality. Location of destination has been generalized for this example.
CHAPTER THREE
DATA PRESENTATION AND ANALYSIS

Introduction

The results of this study are presented below. The following sections: (1) outline the character of the Primary Sample and two supplementary samples, (2) present basic data on trip lengths and travel rates, (3) demonstrate the manner in which trip networks are conceptualized and classified, (4) illustrate two measures of route complexity, and (5) analyze various aspects of trip structure and route choice for the Primary Sample and compare these results with (a) those obtained from observations on a special sample of school children and (b) abstract "trips" reported by subjects asked to give directions for finding one's way to a local landmark.
The first sections in this chapter characterize the Primary Sample and two supplementary samples: The School Children Sample and the Directions Sample. Where appropriate, the age and gender composition of each sample is presented together with data on trip lengths and walking speeds. These introductory sections are followed by more specific discussions of route networks and trip choices.

The Primary Sample

The Primary Sample in this study consists of 200 randomly selected, spatially stratified subjects over the age of five. All subjects in this sample were ethologically tracked and their observed routes recorded. A subset of the Primary Sample was studied further using questionnaire techniques. Whereas tracking resulted in observational data concerning the final portions of pedestrians' trips, the questionnaire data provided reports on the initial, unobserved portions of these trips. This section reviews the characteristics of the Primary Sample and the various subsets within the sample. Particular attention is focused on the subset of the Primary Sample which returned questionnaires with accurate descriptions of the tracked portions of their pedestrian trips: The Primary Corroborated Sample.

Observed vs. Unobserved Trip Segments

Ethological observation began only at randomly selected interception points. When an eligible subject walked through an interception
point, observation commenced and continued until the subject was judged to have reached a "destination". Observational data are lacking for the portion of the trip which was completed prior to the point where the subject was intercepted. Each trip may thus be said to have an inaugural portion which was unobserved and a terminal segment which was observed.

Situation "A" in Figure 3-1 illustrates this graphically. Limiting conditions are shown in Situation "B" (where the interception point is so close to the origin that almost the entire trip comes under observation) and Situation "C" (where the interception point is so close to the destination that little of the trip is observed). The data below will show that Situation "B" did occur several times during observations to the point that, practically speaking, the entire trip was observed. Generally, however, it is convenient to think of trips as having both observed and unobserved components.

Questionnaires were handed to the majority of the subjects after they reached their "destinations" for the purpose of gathering data on the unobserved, inaugural portions of their trips. The result of this methodological procedure is creation of several sub-samples whose relationships to each other warrant at least minimal clarification.

Figure 3-2 presents a Venn diagram which illustrates the hierarchical relationship between several increasingly exclusive datasets within the Primary Sample. First, there are observational data for all those (200) who were ethologically tracked. Within this set, a smaller number (158) were given questionnaires. Of those who
Figure 3-1: Relationship of Interception Point, Origin, and Destination to Proportion of Trip Observed vs. Unobserved

Situation "A"

Situation "B"

Situation "C"

Where,

\[ D = \text{Destination} \]
\[ I = \text{Interception Point} \]
\[ O = \text{Origin} \]

And,

\[ DI = \text{Observed Portion of Trip} \]
\[ IO = \text{Unobserved Portion of Trip} \]
Ethologically Observed
N=200
(100%)

Given Questionnaire
N=158
(79%)

Answered & Returned Questionnaire
N=97
(49%)

Gave Accurate Route Description
N=83
(42%)

The Primary Corroborated Sample
replied to the questionnaire (97), only a portion (83) provided accurate descriptions of those segments of their trips that were observed during tracking. Before turning to specific discussion of these subsamples, however, a few observations concerning the relationship of the Primary Sample as a whole to the population from which it was drawn are presented.

The Primary Sample and the Population: Age and Gender Comparisons

The spatially stratified sampling strategy adopted in this study provided information on trip structures within a wide, representative range of environmental settings. The areal stratification of the sample is underscored because the spatial orientation of the sample bears on the interpretation and generalizability of the sample data in certain situations.

Age: The extent to which the sample approximates various characteristics of the population under study are examined here. Table 3-1 illustrates the reported frequencies of subjects in various age categories compared with the population from which the sample was drawn. Examination of the percentages in Table 3-1 reveals that the spatially stratified sample of people who actually walk underrepresents the middle-age group (22-61 years) by about 14% while the older group (62 years and above) is overrepresented by about 16%. These differences may result from lessened ability to maintain or drive automobiles with advancing age and, hence, the elderly may do more walking. Increased amounts of free time following the advent of retirement may
Table 3-1: Age Distribution in Primary Sample and the Population

<table>
<thead>
<tr>
<th>Age Category</th>
<th>Population</th>
<th>Primary Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-21</td>
<td>48,831 (30.9%)</td>
<td>57 (28.5%)</td>
</tr>
<tr>
<td>22-61</td>
<td>87,927 (55.6%)</td>
<td>83 (41.5%)</td>
</tr>
<tr>
<td>62+</td>
<td>21,278 (13.5%)</td>
<td>60 (30.0%)</td>
</tr>
<tr>
<td>Combined</td>
<td>158,036 (100.0%)</td>
<td>200 (100.0%)</td>
</tr>
</tbody>
</table>

(Source: Advance computer printout of 1980 Census, U. S. Bureau of the Census. Population Data, City of Lincoln, Nebraska.)

Table 3-2: Gender Proportions in Primary Sample and the Population

<table>
<thead>
<tr>
<th>Gender</th>
<th>Population</th>
<th>Primary Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>88,315 (51.4%)</td>
<td>112 (56%)</td>
</tr>
<tr>
<td>Male</td>
<td>83,617 (48.6%)</td>
<td>88 (44%)</td>
</tr>
<tr>
<td>Combined</td>
<td>171,932 (100.0%)</td>
<td>200 (100%)</td>
</tr>
</tbody>
</table>

(Source: Advance computer printout of 1980 Census, U. S. Bureau of the Census. Population Data, City of Lincoln, Nebraska.)
permit more recreational walking for the older group. Much of the 22-61 age group could be expected to be "at work" during the hours when observations were completed. The young age group (under 22 years) is represented in the sample in approximately the same proportion that it has within the population. Except for summer programs, schools were not in session when the observations were made. Students, therefore, could be expected to be "in the streets" in proportion to their numbers in the population.

Gender: Gender composition is important because surveys of pedestrian activity conducted solely within central business districts report a preponderance of males over females. The comparison of sample vs. population gender proportions is provided in Table 3-2. Examination of this table indicates slightly more females and slightly fewer males in the sample than might be anticipated if the population figures are used as a guide. One finds a reversal of the usual CBD study in which males outnumber females. This result probably derives from more comprehensive sampling in this study of a wide range of environmental settings which includes the CBD but is not restricted to it.

Travel Rates in the Primary Sample

Although route selection is the central focus of this study, the results of ethological observation provide information on several related issues, not the least of which is travel rate or velocity.
These data are presented at this point because they provide an additional dimension characterizing the Primary Sample.

Men and women were observed, on average, to travel at almost identical rates of speed (males 275 feet/minute, females 274 feet/minute) based on ethological observation of 200 subjects. Interestingly, the youngest category (5-21 years) was not (at 285 feet/minute) the fastest (although it should be noted that a special sub-sample of school children on their way home from school logged considerably faster rates, cf., Table 3-7).

Those in the middle years (22-61) were the speeders (290 feet/minute). Those more advanced in years (62+) logged a slower mean rate of travel (243 feet/minute). Previous researchers have generally observed that men walk faster than women and this was recorded here too in the 5-21 age group (males 293 feet/minute, females 277 feet/minute) and in the 22-61 age group (males 312 feet/minute, women 277 feet/minute). In the 62 and over age bracket, however, women were considerably more swift (269 feet/minute) than men (208 feet/minute). In general, women appear to maintain a relatively constant travel rate regardless of age group. Men's speeds start out faster, increase to a peak and then "bottom out" in later years as shown in Figure 3-3. While dramatic and suggestive of further research, these differences are not statistically significant at the .01 level.

Relationship of the Primary Sample to the Central Business District

The Primary Sample is not proportionally representative of all
Figure 3-3: Travel Rates by Gender and Age Group in Primary Sample
pedestrian activity within the study area. A simple count of pedestrian activity was effected at intersections within each sample quadrat and mapped using the SYMAP program to generate a surface of generalized pedestrian flow for the study area. This map (Figure 3-4) is based on data reported in Table 2-4. The level of pedestrian activity is not uniformly distributed within the city. The central business district (i.e., Quadrat 4, Figure 2-3) is characterized by relatively very high rates (reaching 355 pedestrians per hour) at each street intersection. Most other parts of the city (particularly residential, suburban areas) experience relatively low rates of pedestrian activity. There are two minor "peaks" of pedestrian flow associated with smaller, outlying business districts. If the Primary Sample in this study had been drawn proportionally to pedestrian activity levels (rather than areally stratified), then the great majority of observations, questionnaires, and interviews would have been restricted to the CBD region.

The extreme difficulty and hard work involved in obtaining a spatially stratified sample of 200 observations prevented the use of sample sizes large enough to allow one to "weight" the observations for each quadrat by the level of pedestrian activity associated with a given quadrat. Nonetheless, data on the ten trips intercepted within the CBD do underline the uniqueness of this pedestrian environment although the sample is far too small to allow any analysis to be pushed very far. The random interception of seven males vs. three females within the CBD is a complete reverse of the sample as a whole
AVERAGE HOURLY PEDESTRIAN FLOW

Source: Table 2-4

Figure 3-4: Generalized Flow Surface
in which females represent 56% and males 44% of those observed. Further, not a single older person over 61 years of age was intercepted within the CBD in comparison to the 30% found in the sample generally. When all ten intercepted CBD trips are averaged on the length dimension, the resulting mean of .38 mile is very close to the average for the sample as a whole (.36 mile). But, if the CBD trips made by the three women are subtracted, the mean for males (.24 mile) drops well below that of the sample as a whole and for men generally (.37 mile). Clearly, this sample is a very small one and does not bear heavy analysis, but it does point to a CBD characterized by numerous young to middle aged males engaged in a large number of relatively short trips. To the extent that many pedestrian-oriented studies have concentrated entirely on CBD pedestrians, it is suggested here that they may be biased in the direction of a male-dominated, business world environment. At the least, this is a question worth further study.

In conclusion, it is noted that a stratified sample of people who walk on weekdays during daylight hours tends to include slightly more women and older people than might be expected based on the population as a whole. It is further noted that the major question addressed by this study concerns the spatial structure of pedestrian trips as a genre. Thus, since it is assumed that trip structure is greatly influenced by unique environmental conditions or possibilities,
the adopted sampling procedure selected from representative environmental conditions within the study area so that the assumed effects of environment may, to some degree at least, cancel each other out. While the results of this study may not be comfortably generalized to specific types of environmental settings, such as the central business district, the results are generalizable to a conception of a representative pedestrian faced with a range of environmental settings and conditions.

**Primary Questionnaire Sample**

Questionnaires were given to 158 (79%) of the Primary Sample to obtain information concerning unobserved portions of pedestrian trips. Questionnaires were not delivered to 42 subjects (21%), generally because they were "lost" by the observer. This figure also includes a handful (nine out of 167 who were offered questionnaires) who refused to accept the questionnaire. Thus the refusal rate was approximately five per cent.

"Losing" a subject most often happened when a subject entered a large, crowded department store, cavernous office building, or extensive apartment complex. It was often difficult in such settings to determine just where the subject had gone. When the researcher lost contact with a subject in a large building, he waited near the main entrance/exit for a period of ten minutes. If the subject did not reappear prior to the elapse of the "ten-minute rule", the subject was classified as having reached a "destination". It was thus
possible, pragmatically, to record the trip as "completed" (although subjects may have "escaped" through unobserved exits), but it was not possible to locate the subject for the purpose of delivering a questionnaire.

Did the subset of "lost" pedestrians have any special characteristics setting it apart from the group to which questionnaires were given? Subjects who were given and not given questionnaires are compared on the dimensions of gender, estimated age, and observed trip segment length in Table 3-3. Tests for significant statistical differences were performed on each of these dimensions. The Chi-square test, applied to the data on age and gender, revealed no significant differences between the two groups at the .01 level. There is, of course, no statistical difference between groups on the dimension of observed trip length. Both groups have a mean of .35 mile. Given the limited scope of these comparative dimensions, no major bias is discernable between those to whom questionnaires were delivered and those who refused or could not be located after they reached their "destination".

**Questionnaire Returns:** Questionnaire return rate was 97 (61%) out of 158 distributed. There is no demonstrable bias in these returns on the dimensions of age, gender, or length of terminal trip segment. While it might be assumed that pedestrians who take longer trips would be more motivated to complete the questionnaires, this was not found to be the case. Summary data comparing the group
Table 3-3: Comparison of Groups Given and Not Given Questionnaires

<table>
<thead>
<tr>
<th>Age</th>
<th>5-21</th>
<th>22-61</th>
<th>62+</th>
<th>5-21</th>
<th>22-61</th>
<th>62+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>42</td>
<td>67</td>
<td>49</td>
<td>15</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>(27%)</td>
<td>(42%)</td>
<td>(31%)</td>
<td>(36%)</td>
<td>(38%)</td>
<td>(26%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>67</td>
<td>91</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>(42%)</td>
<td>(58%)</td>
<td>(50%)</td>
<td>(50%)</td>
</tr>
</tbody>
</table>

Mean Length of Observed Trip Segment

<table>
<thead>
<tr>
<th>Miles</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>.35</td>
<td>.35</td>
</tr>
</tbody>
</table>
which returned questionnaires with the group which did not return questionnaires are presented in Table 3-4.

Application of the Chi-square test to the age and gender data and the T-test on the length data revealed no statistically significant differences between those who did and did not return questionnaires when alpha is set at the .01 level. In the case of gender, however, significance was closely approached. Whereas only about half of all men who accepted a questionnaire actually returned it, nearly 70% of all women who received the questionnaire took time to fill it out and put it in the mail.

Questionnaires were returned with reasonable promptness. This issue is important because questionnaire data were desired concerning the specific trip observed during ethological tracking, not some subsequent trip which a subject might recall and report on at a later date. Date of return was determined from post office cancellations on the return envelopes. 90% of the questionnaires were returned within a week and over half of the questionnaires were returned the day following distribution.

Response Accuracy--The Primary Corroborated Sample: Data were obtained on the observed and unobserved trip segments for nearly half the observed trips. Of the 97 subjects who returned questionnaires, 95 (98%) responded to the request to provide a detailed description or diagram of the route they had just finished walking. Unknown to these subjects, however, at least the final portions of
Table 3-4: Questionnaire Return by Age, Gender, and Trip Length

<table>
<thead>
<tr>
<th>Age</th>
<th>5-21</th>
<th>22-61</th>
<th>62+</th>
<th>5-21</th>
<th>22-61</th>
<th>62+</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>23</td>
<td>45</td>
<td>29</td>
<td>19</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>(24%)</td>
<td>(46%)</td>
<td>(30%)</td>
<td>(31%)</td>
<td>(36%)</td>
<td>(32%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>33</td>
<td>64</td>
<td>34</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>(34%)</td>
<td>(66%)</td>
<td>(56%)</td>
<td>(44%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean Length of Observed Trip Segment</th>
<th>Miles</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.34</td>
<td>.38</td>
</tr>
</tbody>
</table>
of their trips had actually been observed and recorded during the tracking procedure. A method thus became available for checking the accuracy of the subjects' self-reports.

Subjects generally described their trips accurately. 83 (87%) of the 95 subjects who answered the route description request (Question Five, Figure 2-7-C) gave accurate descriptions of those portions of their trips which could be corroborated from observational data. A subject's response was judged "accurate" if it revealed the exact street route to have been taken, including all turns (if any) and correct street identification (either by name, number, geometry, or identifying landmarks).

Only 12 subjects (13%) provided inaccurate trip descriptions. The source of this inaccuracy cannot be determined here, but a few possibilities may be mentioned. "Wrong" answers may have resulted from some idiosyncratic inability on the part of a subject to write a coherent verbal description or to draw graphic images such as maps or diagrams. Other "errors" might be attributed to memory lapse in the subject. Possibly misunderstanding the questionnaire instructions, some subjects may have accurately reported a trip, but not the trip which had been tracked. Finally, the researcher may have made errors in recording the tracking data. Unfortunately, the sample of inaccurate replies is too small for explanatory probing. On the face of it, the small number of inaccurate responses speaks well for the spatial recall abilities of Lincoln pedestrians and the potential efficacy of questionnaires in the study of route selection.
It is assumed here that those subjects who responded with accurate descriptions of the terminal segments of their routes probably provided accurate descriptions of their entire routes, including those portions completed prior to the start of tracking observations. It could be argued against this assumption that the subjects may have been better able to recall the latter portions of their trips (the corroborated segments) than the earlier parts (which are not generally corroborated). However, many of the corroborated portions were relatively lengthy and complex. Some of the corroborated portions encompassed nearly entire trips (having been intercepted very near the actual point of trip origin). There were, in fact, 22 instances (27%) in which the tracked trip was, for all practical purposes, identical to the total trip reported by the subject. Thus, there is at least some minimal reason to believe that those who reported accurately on the terminal segment of their trip also reported accurately on the inaugural portion of their trip.

This subsample is especially important because the information obtained from it concerns complete or entire trips. It is referenced in all further sections in this study as the Primary Corroborated Sample. Table 3-5 provides an overview of the characteristics of this special subsample.

When the Primary Corroborated Sample is compared with the remainder of the Primary Sample from which it derived, Chi-square tests for differences on the dimensions of gender and estimated age reveal no significant differences at the .01 level. Women do, however,
Table 3-5: Primary Corroborated Sample--Summary Characteristics

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Mean Trip Length (miles)</th>
<th>Rate of Travel* (feet/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Observed</td>
<td>Unobserved</td>
</tr>
<tr>
<td>Males</td>
<td>29 (35%)</td>
<td>.25</td>
<td>.19</td>
</tr>
<tr>
<td>Females</td>
<td>54 (65%)</td>
<td>.33</td>
<td>.22</td>
</tr>
<tr>
<td>Combined</td>
<td>83 (100%)</td>
<td>.31</td>
<td>.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Frequency</th>
<th>Mean Trip Length (miles)</th>
<th>Rate of Travel* (feet/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Observed</td>
<td>Unobserved</td>
</tr>
<tr>
<td>5-21</td>
<td>21 (25%)</td>
<td>.38</td>
<td>.18</td>
</tr>
<tr>
<td>22-61</td>
<td>40 (48%)</td>
<td>.27</td>
<td>.25</td>
</tr>
<tr>
<td>62+</td>
<td>22 (27%)</td>
<td>.31</td>
<td>.16</td>
</tr>
<tr>
<td>Combined</td>
<td>83 (100%)</td>
<td>.31</td>
<td>.21</td>
</tr>
</tbody>
</table>

*Rate of travel based on tracked portions of trips only.*
outnumber men in the Primary Corroborated Sample 54 (65%) to 29 (35%) while this ratio is nearly 50:50 (58 to 59) in the remainder of the Primary Sample. Age distribution in the Primary Corroborated Sample follows the same pattern found in the remainder of the Primary Sample with the exception that there are a few more subjects in the middle age group (22-61 years) and a few less subjects in both the younger (5-21 years) and older (62+ years) age categories.

Interestingly, the Primary Corroborated Sample exhibits slightly shorter terminal trip segments than does the rest of the Primary Sample. The mean observed trip segment for the Primary Corroborated Sample was .31 mile while the figure for the remainder of the Primary Sample was .39 mile. A T-test shows this difference is not significant at the .01 level, however.

Length Comparisons: Physical length is one of the most fundamental dimensions of any pedestrian trip. The 200 subjects in the Primary Sample walked an average of .35 mile per terminal trip segment. This figure, however, seriously underrepresents trip length. This is because each observed trip was an "intercepted" or partial trip. Generally, each trip had already been initiated at some more distant point prior to the start of each observation. The following analysis provides an insight on the total length of such trip.

The primary Corroborated Sample reveals a marked increase in the length of complete trips over those partial trips which were tracked.
The complete trips reported by subjects are approximately 0.2 mile longer on average than the tracked portions alone. When the observed and unobserved portions are added together for each trip and a new mean is calculated for the Primary Corroborated Sample, the result is an average trip length of 0.52 mile. The average trip reported by women is 0.55 mile while the mean trip for men is 0.45 mile. This difference, however, does not approach statistical significance at the .01 level. The longest reported walk (2.02 miles) was attributed to a woman. The most lengthy walk reported by a male was 1.51 miles in length.

The median trip length, 0.38 mile, is somewhat lower than the mean for complete trips for the Primary Corroborated Sample. This indicates a tendency on the part of at least a few pedestrians in this subsample to have taken (relatively speaking) extraordinarily long walks. For example, 13 (16% of the pedestrians responding accurately to the questionnaire) reported completing walks measuring one mile or greater in length. The "Long Distance Walkers" are particularly interesting because their existence demonstrates that walking can be a viable mid-range transportation mode. The gender and age characteristics of this special subgroup are shown in Table 3-6.

Unfortunately, the sample is too small to allow much analysis. Yet, it is clear that "long distance walkers" are a reality. The observation that women comprise 85% of this group when they make up only 65% of the subjects who returned accurate questionnaires indicates the possibility that the distaff side may well be making more of the
<table>
<thead>
<tr>
<th>Gender</th>
<th>5-21</th>
<th>22-61</th>
<th>62+</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Totals</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>13</td>
</tr>
</tbody>
</table>
really lengthy trips. This is an hypothesis which bears further research in a future study. The "long distance walker" deserves more attention not only in the planning and transportation sciences, but in the behavioral and social science disciplines as well.

Supplementary Samples

Smaller, supplementary samples were employed to obtain information relevant to (1) trip structures of young children and (2) the spatial structure of information given by subjects asked for directions to a local landmark. The first sample consists of 50 elementary school children who were tracked on their way home from school. This sample is referenced below as the "School Children Sample." The second sample includes 100 subjects who were asked to provide directions to a nearby landmark. This sample is referenced below as the "Directions Sample". The following section provides an overview of these two supplementary samples.

School Children Sample

The characteristics of this sample are relatively straightforward. 19 (38%) subjects were males and 31 (62%) were female. The shortest trip observed was .06 mile and the longest was .83 mile. Mean length of observed trips was .36 mile.

Unlike the ethologically tracked trips in the Primary Sample (which had both unobserved and observed portions), all trips in the School Children Sample were observed in entirety from origin to
destination. Each trip started at the selected school at class dismissal time and the subject was tracked to a destination. Destinations were determined using the "ten-minute rule" discussed above. Questionnaires were not given to subjects in this sample because (1) complete trip descriptions were recovered through observation alone and (2) questionnaire distribution might have proved alarming to parents of very young children. As a result, all information for the School Children Sample is observational in character.

Gender Variations in Trip Length and Travel Rates for the School Children Sample: Summary data on trip length and travel rates are presented in Table 3-7. Here it is seen that mean trip length is nearly identical for both genders. This result should occur in a random sample, especially if it is assumed that all students, regardless of gender, generally go straight home and it is further assumed that the homes of both male and female students are randomly located around the elementary school.

Boys were observed travelling at slightly higher velocities, on average, than girls. This difference, however, is not significant at the .01 level when a T-test is performed. The school children did, on the other hand, travel faster (335 feet/minute) than young subjects (5-21 age group) in the Primary Sample (285 feet/minute). Many children do, in fact, run rather than walk home from school. "Home" is assumed here insofar as the majority of trips (88%) concluded at residential dwellings.
# Table 3-7: Trip Length and Travel Rates for School Children

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Mean Trip Length (miles)</th>
<th>Mean Travel Rate (feet/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>19 (38%)</td>
<td>.38</td>
<td>351</td>
</tr>
<tr>
<td>Females</td>
<td>31 (62%)</td>
<td>.36</td>
<td>324</td>
</tr>
<tr>
<td>Combined</td>
<td>50 (100%)</td>
<td>.36</td>
<td>335</td>
</tr>
</tbody>
</table>
**Directions Sample**

100 randomly selected subjects were asked by a disguised interviewer to provide directions for walking to a nearby landmark. Males (56%) are more frequently represented in this sample than are women (44%). Insofar as all the directions interviews were conducted on weekends, it is possible that males who are normally "at work" Monday through Friday are more frequently encountered on neighborhood streets on Saturdays and Sundays.

Not all subjects interviewed gave directions which would actually lead a pedestrian to the intended destination. "Accuracy" of responses was determined using the same criterion employed in the previous analysis of questionnaires responses for the Primary Sample. Whereas 78 subjects were judged to have given accurate replies, seven subjects gave inaccurate directions and 15 subjects said they "Didn't know" where the landmark was located and then indicated that they couldn't, therefore, give directions to it. Those who admitted not knowing the location of a target were generally very apologetic for their lack of neighborhood knowledge. It might be ventured that some subjects gave "false" directions rather than admit that they did not know where the landmark was located.

For purposes of analysis, the two categories "Inaccurate response" and "Didn't know" were combined in order to obtain expected cell frequencies required for application of the Chi-square test. These combined categories are referenced as "Not Accurate" in Table 3-8.
Table 3-8: Age and Gender Differences in Direction Accuracy

<table>
<thead>
<tr>
<th>Gender</th>
<th>Accurate</th>
<th>Not Accurate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>46</td>
<td>10</td>
<td>56</td>
</tr>
<tr>
<td>Females</td>
<td>32</td>
<td>12</td>
<td>44</td>
</tr>
<tr>
<td>Combined</td>
<td>78</td>
<td>22</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Accurate</th>
<th>Not Accurate</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-21</td>
<td>10</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>22-61</td>
<td>58</td>
<td>13</td>
<td>71</td>
</tr>
<tr>
<td>62+</td>
<td>10</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Combined</td>
<td>78</td>
<td>22</td>
<td>100</td>
</tr>
</tbody>
</table>
The table indicates that males gave slightly more accurate responses (82%) than did females (73%), but this difference is not statistically significant at the .01 level. Analysis of subjects' estimated ages is not possible due to small expected cell frequencies. The data, however, are reported for inspection in Table 3-8. The middle age group (22-61 years) gave slightly more accurate responses (82% accurate) than did the younger subjects (71% accurate) or the more elderly group (67%) accurate.

**Directions Accuracy as a Function of Distance:** If it is assumed that spatial knowledge deteriorates in comprehensiveness given ever larger regions for which one is expected to be knowledgeable or experienced, it is possible to hypothesize that increased distance to the landmark should be associated with increased errors in giving directions to the landmark. Distances to target landmarks ranged, in this study, from a minimum of .13 mile to a maximum of .87 mile. The mean and median for this distribution were identical: .48 mile. Mean target distance of "Inaccurate" and "Didn't know" categories combined was .56 mile whereas the mean distance for accurate replies was .47 mile. Thus, the data reveal a slight tendency for more errors and/or less spatial knowledge with increasing distance from the landmark. These differences, however, are not statistically significant at the .01 level. This result suggests that accurate spatial knowledge of nearby landmarks is not much affected by distance within a .87 mile range. Significant differences might have appeared, however, if more distant target landmarks had been included in the study. But,
neighborhood elementary schools were chosen as landmark targets in this study precisely because it was hoped that residents would know their location and be able to offer a suggested route for walking to them.

**Age and Gender Variations in Length of Accurate Trip Directions:**

Summary data on the length of trip directions given by subjects who responded accurately are presented in Table 3-9. Here, it is seen that there is no difference in length of directions on the gender dimensions. This follows from the geometry and random nature of the sample combined with the finding (Table 3-8) of essentially equal ability on the part of subjects regardless of gender to provide accurate directions to target landmarks.

Data on length of directions by age group are also reported in Table 3-9. Inspection reveals that the younger subjects were faced with the task of giving directions to slightly more distant targets, on average, than were their elders. These differences are not statistically significant when an analysis of variance is performed. Since there is no plausible alternative explanation (except for the whimsical notion that school-aged children might attempt to spend their weekend days as far away as possible from any school building), it is assumed that the age differences in Table 3-9 are due to random fluctuations in subject selection.
<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Mean Length (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>46 (59%)</td>
<td>.47</td>
</tr>
<tr>
<td>Females</td>
<td>32 (41%)</td>
<td>.47</td>
</tr>
<tr>
<td>Combined</td>
<td>78 (100%)</td>
<td>.47</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Frequency</th>
<th>Mean Length (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-21</td>
<td>10 (13%)</td>
<td>.57</td>
</tr>
<tr>
<td>22-61</td>
<td>58 (74%)</td>
<td>.45</td>
</tr>
<tr>
<td>62+</td>
<td>10 (13%)</td>
<td>.45</td>
</tr>
<tr>
<td>Combined</td>
<td>78 (100%)</td>
<td>.47</td>
</tr>
</tbody>
</table>
Summary: Three Samples of "Complete Routes"

Data collection resulted in establishing three samples which all provide information on "complete" trips from "origins" to "destinations". These three samples are the Primary Corroborated Sample (N=83), the School Children Sample (N=50) and the Accurate Directions Sample (N=78). These samples result from application of a variety of methodological techniques: tracking combined with questionnaires, tracking used alone, and disguised interviews, respectively.

These samples represent a variety of subject characteristics, situational dimensions, and trip attributes. Comparison of Tables 3-5, 3-7, and 3-9 provides an overview of the differences and similarities between these groups. It should be recalled that the Primary Corroborated Sample represents weekday trips when regular school is not in session. The Directions Sample taps weekend "conceptual" trips when regular school is not in session whereas the School Children Sample is focused on very young subjects during weekdays when school is in regular session.

On the dimension of gender, the Primary Corroborated Sample (65% female, 35% male) and the Accurate Directions Sample (41% female, 59% male), are statistically different at the .01 level. This result is probably a function of weekday/weekend differences in population composition from which the samples were drawn. No statistically significant differences were found at the .01 level between (1) the Primary Corroborated Sample and School Children Sample or (2)
Accurate Directions Sample and the School Children Sample.

With regard to age group composition, all three samples are relatively unique. A statistically significant difference at the .01 level was found between the Primary Corroborated Sample and the Accurate Directions Sample. Again, this result is thought here to be a function of weekday/weekend differences in population composition. The School Children Sample contains only youngsters of elementary school-age, resulting in empty cells when Chi-square tests for significant differences were routinely conducted. The special nature of the School Children Sample is so obvious, however, that a statistical demonstration is not required.

Finally, the samples may be compared on the dimension of mean trip length. T-tests demonstrated that the mean (.52 mile) for the Primary Corroborated Sample and the mean (.47 mile) for the Accurate Directions Sample were not significantly different at the .01 level. The mean (.36 mile) for the School Children Sample was, however, significantly shorter than the mean for either of the other samples.

The above comparisons are summarized graphically in Figures 3-5 through 3-7. Each sample permits different inquiries and insights into the spatial structure and decision-making aspects of pedestrian route-selection. Whereas each sample differs from the others in some respect and is similar in another, all three samples represent various dimensions of complete pedestrian trips from a start to a destination.
Figure 3-7: Inter-Sample Relationships--Trip Length Differences

- Primary Corroborated Sample
  - Not Significant
  - Significant

- Accurate Directions Sample
- Significant
- School Children Sample
The Elements of Spatial Structure: Open and Closed Nodes

The following sections review the manner in which spatial structure and route choice are conceptualized and operationalized in this study. General classifications are devised for identifying (1) types of network structures in which trips take place and (2) trip types within these structures. Subsequently, two standardized indices for complex routes are developed: (1) a Spatial Structure Index which reflects the number of turns in a route relative to the maximum and minimum number of possible turns and (2) a Choice Ratio Index which reflects the extent to which a given route minimizes or maximizes a pedestrian's "freedom of choice" while walking. These classifications and indices are illustrated and discussed individually in the sections below. First, however, it is necessary to introduce two concepts which are needed for the further development of this discussion: open and closed nodes.

The concepts of "open" and "closed" nodes are the building blocks for the classifications and indices which follow. In this scheme, a "trip" is defined as a sequence of moves between nodes strung along a path. Using the vocabulary of graph theory, each node is a vertex and each link in a path is an edge. These terms are operationalized in the following manner. "Nodes" are interpreted as street intersections and "paths" are viewed as streets (including any sidewalks running parallel to them) which run from intersection to intersection. Consider the "real world" example mapped in Figure 3-8.
Figure 3-8: Streets and Intersections in a Portion of Lincoln

Figure 3-9: Streets and Intersections Shown as Edges and Nodes
In Figure 3-8, there is a series of streets (i.e., 12th, 11th, 10th, 9th, and "N") and a series of street intersections (i.e., 12th and "N", 11th and "N", etc.). Since each street may be represented as an edge and each intersection as a vertex, the map in Figure 3-8 may be re-drawn as shown in Figure 3-9. Since a node is defined as a street intersection, it is not always necessary to show all of the streets involved. For example, the diagram in Figure 3-9 can be given even more sparse expression as shown in Figure 3-10. In this figure, each "dot" is a node representing a street intersection. This simplified diagram can provide a shorthand "map" of a pedestrian's route from, let us say, 12th and "N", via "N" to 9th and "N". Thus, 12th and "N" becomes the "start" of the trip whereas 9th and "N" is the "destination". The symbol "S" is used to stand for start and "D" to signify a destination. The essential spatial structure of a trip from a start at 12th and "N", via "N" to a destination at 9th and "N" is thus captured by the diagram in Figure 3-11. This example illustrates a trip which starts and then passes through two intermediate nodes along the way to a destination. Insofar as interest is in spatial structure per se, the actual street names involved cease to be of primary concern. It is the general structure of the array of nodes and the links which connect them that become the main focus.

The nodes in Figure 3-11 are said to be "closed" nodes. At a closed node, the subject's "choice" of which node to select next has no degrees of freedom for one reason or another. The "reason" in this
Figure 3-10: Further Abstraction of Streets and Intersections

![Diagram showing streets and intersections labeled 12th, 11th, 10th, 9th, and "N" Street.]

Figure 3-11: Example of Essential Spatial Structure of a Trip

![Diagram showing "S" and "D".]
study is that all trips are assumed to be governed by the Primary Strategy of Distance Minimization. An example may help illustrate why the nodes in Figure 3-11 are "closed". If a pedestrian wishes to walk from the start to the destination in Figure 3-11 and also wishes to take the shortest possible path, then there is no choice but to walk through the two intervening nodes between the start and the destination. Looked at another way, when a pedestrian reaches one of these intervening nodes, he/she is not at liberty to make a turn and follow a side street if the goal is to get to "D" by the shortest path. It is through this line of reasoning that the nodes in Figure 3-11 are called "closed" nodes: the side streets which intersect with the main route are "closed" to the pedestrian if he/she is following a "distance minimization strategy" during path selection. It is assumed throughout the remainder of this discussion [following Zipf's (1949) least effort thesis] that pedestrians always seek a shortest path.

There are situations, however, when nodes may be characterized as "open". Consider the diagram in Figure 3-12 in which each node is given an identifying subscript. Assume that a pedestrian wishes to walk from "S" to "D". When Node₄ is reached, there is a choice to be made. One must decide whether to keep going straight, toward Node₃, or to make a turn toward Node₁. Nodes where choices of this sort must be made are defined as "open" nodes. A further graphic convention is introduced here. "Open" nodes are identified by a circle with a clear center (○), whereas "closed" nodes are circles with filled-in or dark centers (●). Many real-world trips involve passing through some
Figure 3-12: Illustration of an "Open" Node

Figure 3-13: Trip Network Embedded in a Larger Transportation Network
combination of both open and closed nodes. These two concepts are useful in presenting the more formal explication of network types below.

**Trip Network Classification**

A trip network is composed of all links and nodes from which a pedestrian could select when choosing a route from "S" to "D". In this study, such a network is restricted to include only those nodes and links which could be included in a least distance route from "S" to "D". The nature of this restriction is illustrated in Figure 3-13. In this example, a trip network is embedded in a larger network of nodes and links. The intersections or nodes designated with the symbol (▽) are not part of the trip network because they cannot be reached in any trip from "S" to "D" without violating the distance minimization rule. This condition also holds for the links indicated (in this example only) by dashed lines (-----).

Although all references to trip networks in this analysis refer to trip networks in this restricted sense, it should not be forgotten that all trip networks are embedded in a larger network of links and nodes which comprises the general transportation network of the study site as a whole.

**Linear Networks**

A linear network is composed completely of closed nodes. The example in Figure 3-11, discussed above, is a linear network. Such
networks need not be straight lines, however. A linear network can have turns in it and, on the surface, appear to be somewhat complex. Figure 3-14 illustrates such a network. This situation can occur when the intersecting streets turn out to be "dead ends" or cul-de-sacs, when schools or large buildings occupy an over-sized lot, or when a street has been completely barricaded for construction work.

Split Networks

An illustration of a split network has already been encountered in Figure 3-12. A split network has at least one open node and if there are two or more open nodes none of these open nodes may be adjacent to each other. Variations are illustrated in Figures 3-15-A and 3-15-B. These networks are called "splits" because they are reminiscent of the image of a country traveller encountering an obstacle in the middle of a path. The traveller must decide which way to go around the obstacle. He/she may turn "left" or "right".

Figure 3-15-B demonstrates the case where there are two "splits". Note that the two open nodes are not adjacent, but are separated by Node_1 and Node_2 respectively. Although split networks with multiple open nodes are logical possibilities, they were never encountered during the course of empirical investigation in this study. Thus, for practical purposes, it may be assumed that a split network usually has only one open node plus any number of closed nodes.
Figure 3-14: Example of a Linear Network

Figure 3-15-A and 3-15-B: Examples of Split Networks
Complex Networks

A complex network has at least two or more adjacent open nodes. The most simple case is illustrated in Figure 3-16. Note that open Node 1 and open Node 2 are both adjacent to each other. A much larger complex network is illustrated in Figure 3-17. In this network the number of open nodes actually surpasses the number of closed nodes. Such networks are frequently encountered by pedestrians in cities with street systems based on the rectangular or "Manhattan" grid plan. Here, there is a vast field of open nodes which give the pedestrian considerable flexibility in choosing a route from "S" to "D".

Summary

Using the concepts of "open" and "closed" nodes, it has been possible to construct a classification of network types: (1) Linear, in which all nodes are closed, (2) Split, which have at least one open node but never adjacent open nodes, and (3) Complex, wherein there are at least two adjacent open nodes. Generally speaking, each network type from linear through split to complex challenges the pedestrian with increasing levels of decision-making flexibility.
Figure 3-16: Example of a Complex Network

Figure 3-17: Additional Example of a Complex Network
Empirical Dimensions of Network Types

The classification explicated above provides a useful framework for analyzing the empirical dimensions of network types. This section examines (1) the frequency each network type was encountered by subjects in this study and (2) the mean length of each network type. Network "length" is defined here as the measured length (in miles) of the shortest distance path through a network.

Table 3-10 presents data on the trip networks in which 200 subjects in the Primary Sample completed terminal trip segments. The majority (76%) of subjects were observed to effect their trips in linear networks. Note also that the mean length of these linear networks is shorter than that of split or complex networks. Further inspection of Table 3-10 reveals an upward progression in mean trip length as one moves hierarchically from linear to split to complex networks. An analysis of variance for network length by type of network shows these hierarchical increases in network length to be significant at the .01 level. These data, however, refer to "partial" rather than "complete" trips.

Shifting attention to the Primary Corroborated Sample permits a clearer picture of network types utilized for "complete" trips. The relevant data are summarized in Table 3-11. Compared with the data in Table 3-10, it is seen here that the proportion of linear networks is reduced from 76% to 64% whereas there is a small increase in the proportion of split networks and an increase of 10% in the proportion
Table 3-10: Network Types for Terminal Segments in Primary Sample

<table>
<thead>
<tr>
<th>Network Type</th>
<th>Frequency</th>
<th>Mean Length (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>152 (76%)</td>
<td>.26</td>
</tr>
<tr>
<td>Split</td>
<td>10 (5%)</td>
<td>.41</td>
</tr>
<tr>
<td>Complex</td>
<td>38 (19%)</td>
<td>.73</td>
</tr>
<tr>
<td>Combined</td>
<td>200 (100%)</td>
<td>.35</td>
</tr>
</tbody>
</table>

Table 3-11: Network Types for Primary Corroborated Sample

<table>
<thead>
<tr>
<th>Network Type</th>
<th>Frequency</th>
<th>Mean Length (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>53 (64%)</td>
<td>.38</td>
</tr>
<tr>
<td>Split</td>
<td>6 (7%)</td>
<td>.31</td>
</tr>
<tr>
<td>Complex</td>
<td>24 (29%)</td>
<td>.87</td>
</tr>
<tr>
<td>Combined</td>
<td>83 (100%)</td>
<td>.52</td>
</tr>
</tbody>
</table>
of complex networks. These results point to the conclusion that network length is positively associated with network type. First, the simple linear networks are, on average, shorter than more complex networks. Second, as mean trip length (i.e., .35 mile for terminal trip segments in Primary Sample vs. .52 mile for complete trips in the Primary Corroborated Sample) is increased there is a decrease in the proportion of linear networks and an increase in the proportion of complex networks.

The only data in Table 3-11 inconsistent with the conclusion above are those pertaining to the mean length of split networks. In this case the mean length of split networks is actually less than is reported for split networks in Table 3-10. It is assumed here that this result may well be a random fluctuation due to small sample sizes for split networks (i.e., ten cases in Table 3-10 vs. six cases in Table 3-11). Otherwise, the length pattern remains the same: linear networks are much shorter than complex networks. Again, these differences in network length by network type are significant at the .01 level when an analysis of variance is performed.

Similar patterns are found in data from the School Children Sample and the Accurate Directions Sample. The relevant data are summarized in Table 3-12 and 3-13 respectively. Data in both tables corroborate the association of increased network complexity with increases in network length. For both tables, differences in network length by network category are significant at the .01 level when an analysis of variance is performed.
### Table 3-12: Network Types for School Children Sample

<table>
<thead>
<tr>
<th>Network Type</th>
<th>Frequency</th>
<th>Mean Length (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>31 (62%)</td>
<td>.30</td>
</tr>
<tr>
<td>Split</td>
<td>8 (16%)</td>
<td>.33</td>
</tr>
<tr>
<td>Complex</td>
<td>11 (22%)</td>
<td>.57</td>
</tr>
<tr>
<td><strong>Combined</strong></td>
<td><strong>50 (100%)</strong></td>
<td><strong>.36</strong></td>
</tr>
</tbody>
</table>

### Table 3-13: Network Types for Accurate Directions Sample

<table>
<thead>
<tr>
<th>Network Type</th>
<th>Frequency</th>
<th>Mean Length (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>23 (30%)</td>
<td>.32</td>
</tr>
<tr>
<td>Split</td>
<td>8 (10%)</td>
<td>.44</td>
</tr>
<tr>
<td>Complex</td>
<td>47 (60%)</td>
<td>.55</td>
</tr>
<tr>
<td><strong>Combined</strong></td>
<td><strong>78 (100%)</strong></td>
<td><strong>.47</strong></td>
</tr>
</tbody>
</table>
Tables 3-12 and 3-13 do pose one seeming incongruity, however. The proportion of complex networks is much higher in the Accurate Directions Sample (60%) than in the School Children Sample (22%). This difference was unexpected since children walking home from school could be expected to face networks every bit as complex as those faced by subjects asked to give directions to the nearest elementary school. Yet, the frequencies of networks in each network category are significantly different at the .01 level when the two samples are compared using the Chi-square test. Since this difference is only marginally attributable to chance factors, other explanations are now considered.

The networks utilized by school children were, however, shorter on average (.36 mile) than those presented to the directions sample (.46 mile). A T-test reveals these means to be significantly different at the .01 level. Since network complexity appears to be associated with increases in network length, this finding undoubtedly accounts for some part of the higher proportion of complex networks in the Accurate Directions Sample.

Still, why should the network lengths for the School Children Sample be so much shorter? This may have resulted from the observed fact that many parents chauffeur their children home from school by private automobiles. None of the schools selected as sampling points provided bus services, but relatively long lines of automobiles formed in front of the selected schools just prior to class dismissal time. It seems reasonable to argue that the tendency for parents to trans-
port their children home from school automobile increases with the distance between home and school. If so, students who might otherwise face relatively lengthy, complex networks were removed from the sample. It is also possible that families with children of elementary school age make some effort to locate their homes near the schools attended by their children.

In conclusion, the reader is reminded of two patterns which emerge from inspection of the data on network types encountered in various samples employed in this study. First, the networks faced by school children and by those in the Primary Corroborated Sample are overwhelmingly linear (64% and 62% respectively). These figures are especially important because they represent the network types encountered by people who took actual trips. Second, a general association was found between network type and network length. Given the geometry of the street network and the random allocation of origins and destinations, networks tend to be more complex with increased network length.
Trip Classification

The type of trip available to a pedestrian is often highly constrained by the type of network structure in which the trip is executed. As shall be seen, there is an increasing amount of freedom or choice available to the pedestrian as one moves from linear to split to complex networks. In this and subsequent sections, a dashed line (-------) is used to indicate a route along an adjacent link in a given network. In the same way that networks were presented above, trips are classified here as either linear, split, or complex.

Linear Trips

All of the nodes encountered in a linear trip are closed. Thus, it is only possible to take a linear trip in a linear network. Conversely, linear networks are the only ones in which linear trips are possible. The only "choice" available to the pedestrian is whether or not to start the trip in the first place.

Split Trips

Split networks present the pedestrian with a minimal degree of route choice. When the pedestrian reaches the isolated open node in a split network, a decision must be made. Consider the examples in Figures 3-18-A and 3-18-B where pedestrian's routes are illustrated by dashed lines. In case 3-18-A, the pedestrian opts for a "left" turn and in case 3-18-B, a straight path is chosen which, relative to the
Figures 3-18-A and 3-18-B: Examples of Split Trips

3-18-A, a "left-handed" trip.

3-18-B, a "right-handed" trip.

Figure 3-19: Boundary Routes in a Complex Network

(left boundary route)

(right boundary route)
route selected in 3-18-A, can be considered a "right-handed" choice. Thus, in a split network, trips may be classified as (1) left-handed or (2) right-handed.

In theory, there is a third possibility which could occur in a split network with multiple, nonadjacent open nodes (as in Figure 3-15-B). In such networks, a pedestrian could make a "left-handed" choice at one open node and a "right-handed" choice at the other. This possibility is called a "mixed" trip. While the "mixed" category is a logical possibility, it was never observed simply because no multiple open node split networks were encountered empirically during this study. Thus, for the practical purposes of this study, split trips are easily classified as either "left" or "right".

**Complex Trips**

Complex networks present a much expanded range of route choice options to the pedestrian. First, a pedestrian may elect to follow one of the outer boundaries of a complex network. Examine the two boundary route possibilities illustrated in Figure 3-19. Based on the decision made by the pedestrian when the first open node is reached, the two boundary routes may be identified as either "left" or "right" in the same manner that split trips were identified. Thus, one option in a complex network is to opt for a boundary route and to choose whether it will be a "left" or "right" choice.
The characteristic which most clearly sets a complex network apart from its less complicated cousins is the fact that it has what may be called an "interior". The most simple case is illustrated in Figure 3-20. The link from Node₂ to Node₅ is an interior path which cuts between the boundary links between Node₁ to Node₄ and Node₃ to Node₆. A trip which utilizes at least one such interior link may be called an interior trip.

The number of different interior routes increases almost geometrically given an increasingly large number of adjacent open nodes in a complex network. Consider the relatively small network illustrated in Figure 3-21. In this example, three routes, identified "a", "b", and "c", illustrate the variety of interior routes in the network. While only three trips are illustrated in Figure 3-21, there are, in fact, eight different routes in this network which make use of at least one interior link.

The number and variation of route structures within large, complex networks are not well-captured by the dichotomous categories "left/right" or "boundary/internal". The intricate aspects of complex trips are better differentiated using parametric approaches detailed in the following sections on the Spatial Structure Index and the Choice Ratio Index. Nonetheless, the rudimentary classification outlined above provides an introduction to route structures and captures the fundamental dimensions of route structures in linear and split networks.
Figure 3-20: Example of Interior Route in a Complex Network

Figure 3-21: Additional Examples of Interior Routes
Indices of Trip Structure in Complex Networks

The trip classification presented above reveals little concerning the potential structural intricacy of trips completed in complex networks. As a remedy, two indices of trip structure in complex networks are explicated below. These measures are meaningful only when computed for trips completed in complex networks.

Spatial Structure Index

The number of turns in a given route provides a clue to its spatial structure. Above, a complex trip was defined as one with many turns in it. Conversely, a simple trip has few turns. The terms "many" and "few" are relative, however. Simply counting the number of turns in a given path is not, in itself, particularly illuminating unless one is comparing two trips effected within the same (or an identical) trip network.

A path characterized by few turns but effected in a large, complex network is not structurally equivalent to a path having the same number of turns but effected within a much smaller, complex network. Structurally, the latter case represents a more complex situation. Consider the following examples (Figures 3-22 and 3-23) which illustrate two complex networks of different sizes. In Figure 3-22, the maximum number of turns which could be incorporated in a path is four whereas in Figure 3-23, it is possible for a pedestrian to choose a path with as many as ten turns. Thus, the route illustrated in
Figure 3-22 is a route with the maximum possible number of turns. The route depicted in Figure 3-23 also makes four turns, but falls far short of making the maximum possible number of turns. Intuitively, the route in Figure 3-22 is more complex relative to the possibilities for making turns than is the route in Figure 3-23.

Figures 3-24 and 3-25 illustrate a converse situation in which the trip networks both permit the same maximum number of turns but have different minimum turn possibilities. Further, Figure 3-25 introduces the kind of "irregularities" which often characterize trip networks encountered in the empirical world where parks, closed streets, cul-de-sacs, and extra-long blocks interrupt the regular, symmetrical pattern of an ideal "Manhattan" grid. In both networks, a pedestrian may take as many as eight turns. While a pedestrian making a trip in the network illustrated in Figure 3-24 could choose a path with as few as two turns, a trip effected in the network shown in Figure 3-25 must make at least four turns. Thus, taking a path with three turns in Figure 3-24 demonstrates more turn taking than necessary than does taking four turns in Figure 3-25. Thus, a three-turn route in Figure 3-24 is, intuitively, more complex than a four-turn route in Figure 3-25.

Such simple inspection does not always reveal which of two routes is the more complex. For example, assume (a) a route with five turns effected in a network with a minimum turn possibility of two and a maximum of seven and (b) a route with 13 turns in a network with a
Figure 3-22: Complex Trip with Four Turns--Small Network

Figure 3-23: Complex Trip with Four Turns--Large Network
Figure 3-24: A Regular Complex Network

Figure 3-25: An Irregular Complex Network
a minimum turn possibility of 11 and a maximum of 16 turns. Which route is the more complex? How does the complexity of these routes compare with the routes discussed in Figures 3-22 through 3-25?

The Spatial Structure Index (SSI) provides answers to the questions posed above. This measure allows objective comparison of route complexity for paths effected in networks of radically different size and configuration. The parametric properties of the index also permit the analysis of route "complexity" as a function of other variables. The index is a standardized measure of the number of turns incorporated in a given trip relative to the maximum and minimum number of turns which could have been taken. The index devised here is based on a ready adaptation of the formula for computing standardized scores (Z-scores) and has the following form:

\[
SSI = \frac{\left( \frac{\text{turns in trip}}{\text{max turns}} + \frac{\text{turns in trip}}{\text{min turns}} \right) - 2}{\sqrt{\left[ \left( \frac{\text{max turns}}{2} \right) - \left( \frac{\text{min turns}}{2} \right) \right]^2 + \left[ \left( \frac{\text{max turns}}{2} + \frac{\text{min turns}}{2} \right) \right]^2}}
\]
This measure has a maximum value of 0.7071, a mean of 0.0, and a minimum value of -0.7071 regardless of the size or shape of the network involved. A value of -0.7071 results when a trip with the least possible number of turns has been chosen. Conversely, a value of 0.7071 is found when a trip with the maximum possible number of turns has been selected. In short, SSI is a measure of the relative "straightness" or "crookedness" of a given path relative to the network in which it was executed. It is in this sense that the measure is said to reflect the spatial structure of a given trip.

A few worked examples are in order. Attention is returned to the routes illustrated in Figures 3-22 and 3-23 wherein two routes characterized by four turns, but effected in networks of different size, are hypothesized. Relevant data for comparing these two routes are displayed in Table 3-14. Here, the intuitive conclusions reached above are verified in a standardized, objective manner. The path in Figure 3-23 is less "crooked" than the path in Figure 3-22. The intuitive terms: "crooked" and "straight" are somewhat colloquial. They are replaced here with the terms "complex" and "simple", respectively. A simple route is characterized by negative SSI values with the most extremely simple case receiving the value -0.7071. Conversely, a complex route is characterized by positive SSI values with the most extremely complex case receiving the value 0.7071.

Additional examples of SSI calculation are found in Table 3-15. Here, it is seen that the hypothesized three-turn route in Figure
Table 3-14: Date for Example Calculations of Spatial Structure Index

From Figure 3-22

<table>
<thead>
<tr>
<th>Path</th>
<th>Turns in Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Turn Path</td>
<td>2</td>
</tr>
<tr>
<td>Maximum Turn Path</td>
<td>4</td>
</tr>
<tr>
<td>Hypothetical Trip</td>
<td>4</td>
</tr>
</tbody>
</table>

Computed SSI for Hypothetical Trip = 0.7071

From Figure 3-23

<table>
<thead>
<tr>
<th>Path</th>
<th>Turns in Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Turn Path</td>
<td>2</td>
</tr>
<tr>
<td>Maximum Turn Path</td>
<td>10</td>
</tr>
<tr>
<td>Hypothetical Trip</td>
<td>4</td>
</tr>
</tbody>
</table>

Computed SSI for Hypothetical Trip = -0.3536
Table 3-15: Data for Example Calculations of Spatial Structure Index

From Figure 3-24

<table>
<thead>
<tr>
<th>Path</th>
<th>Turns in Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Turn Path</td>
<td>2</td>
</tr>
<tr>
<td>Maximum Turn Path</td>
<td>8</td>
</tr>
<tr>
<td>Hypothetical Trip</td>
<td>3</td>
</tr>
</tbody>
</table>

Computed SSI for Hypothetical Trip = -0.4714

From Figure 3-25

<table>
<thead>
<tr>
<th>Path</th>
<th>Turns in Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Turn Path</td>
<td>4</td>
</tr>
<tr>
<td>Maximum Turn Path</td>
<td>8</td>
</tr>
<tr>
<td>Hypothetical Trip</td>
<td>4</td>
</tr>
</tbody>
</table>

Computed SSI for Hypothetical Trip = -0.7071
3-24 is, in fact, slightly more complex than a four-turn route hypothesized for Figure 3-25. Comparing Tables 3-14 and 3-15, it is also discovered that the four-turn route shown in Figure 3-23 is just slightly less complex than the three-turn route hypothesized for the network in Figure 3-24. These worked examples demonstrate the utility of the Spatial Structure Index for measuring and comparing relative degrees of route complexity.

Limitations to the Spatial Structure Index

This index has a special quirk which should be noted. When it is calculated for trips effected in linear or split networks, the resulting value, regardless of the number of turns in a route, is always zero. In linear and split networks, the maximum and minimum number of turns are always equal. As a result, both the denominator and the numerator of the Index always resolve to zero values. Hence, the Spatial Structure Index is meaningful only when computed for routes effected in complex networks. In complex networks, a zero value is meaningful and characterizes routes which are "halfway" between extreme complexity and extreme simplicity.
**Choice Ratio Index**

The Choice Ratio Index (CRI) is a standardized measure of the extent to which a pedestrian selects routes with more (rather than fewer) "closed" nodes. This measure is viewed as an indicator of "freedom"-seeking or "freedom preservation" during the completion of a given trip. This conception of "freedom" requires further explanation.

The concept of "freedom" in the sense used here is more easily introduced if the boundary-following discussion (Figure 3-19, reproduced below in Figure 3-26 for easy reference) is recalled. Again, note that there is a "left-handed" boundary route and a "right-handed" one. Regardless of which route is followed, the same number of nodes is encountered. Yet, the proportion of closed to open nodes is not the same in both cases. In the left boundary route, the proportion is 3:4. In the right boundary route, it is 5:2. On this basis, it is said that the "right-handed" route is "less free". The logic of this conclusion is explicated below.

Each open node encountered in a trip means that the pedestrian must make a choice about which link to take next. Conversely, when a pedestrian reaches a closed node, there is no longer any choice concerning the next link to take. That choice has already been "fixed" through a combination of geometry and the "rule" of minimized trip distance.

In a network which is a regular lattice, the open nodes are
Figure 3-26: (Reproduction of Figure 3-19)

Figure 3-27: Example of a Route Which Preserves Choice Options
always encountered during the first stages of a trip. These open nodes are then followed by at least a few closed nodes. In this class of networks (which includes the network in Figures 3-26 and 3-27), the closed nodes always lie on the two boundaries adjacent to the destination. Once the pedestrian selects any closed node, all subsequent nodes will also be closed nodes. In this sense, the two boundaries filled with closed nodes may be called "absorbing boundaries", since, once they are entered, there is no "escape" under the rules of the distance minimization game. It is hopefully clear that a pedestrian who wants to keep her/his options "free" to be able to pick and choose between links while completing a walk must avoid becoming trapped in an absorbing boundary of closed nodes. Consider the path illustrated in Figure 3-27. In this trip, the closed/open node ratio is 2:5, a marked reverse of the ratios (i.e., 3:4 and 5:2) noted for the two boundary routes illustrated in Figure 3-26. Because this path incorporates more open nodes than closed nodes, it is said to be "freer" than the boundary routes. This "free" path preserves the route composition options of the pedestrian as he/she walks along toward a destination.

Computation of the Choice Ratio Index (CRI) is identical to the procedures used to produce the Spatial Structure Index with the exception that closed/open node ratios are substituted in place of turn data. The value range of the CRI is the same as that for the SSI. The maximum is 0.7071, the mean is 0.0, and the minimum is
-0.7071. A large negative value indicates a tendency toward maximum freedom, i.e., the choice of routes with as many open nodes as possible. A large positive value indicates a tendency toward maximum determinancy, i.e., the choice of routes with as many closed nodes as possible. A value of 0.0 indicates a course halfway between maximum freedom and maximum determinancy. As in the case of the SSI, these values are standardized so that routes effected in networks of radically different size and configuration may be compared on the freedom/determinancy dimension.

A worked example is in order. Consider the routes shown in Figures 3-28 and 3-29. The SSI for both routes is 0.1414, leaning slightly toward complexity. Although the SSI for these two routes is identical, the CRI values are not the same, as shall be seen below. This result stems from differences in the geometry of the two networks. While Figure 3-28 illustrates a complete regular lattice, Figure 3-29 shows a lattice which is, in a sense, "incomplete". Some links are "missing" and not all of the "blocks" are of the same, uniform size. Figure 3-29 also illustrates what may be called internal closed nodes, i.e., closed nodes that do not lie on an absorbing boundary. See, for example, Node₁ and Node₂ in Figure 3-29.

The ratio of closed to open nodes for the indicated route in Figure 3-28 is 3:5 (= 0.6000). In Figure 3-29, the ratio for the indicated route is 4:4 (= 1.0000). Computation of the CRI allows the researcher to compare these ratios relative to the largest and
Figure 3-28: Example Network for Choice Ratio Index Calculations

Figure 3-29: Example Network for Choice Ratio Index Calculations
smallest ratio values in each network. The largest ratio represents
the path(s) with maximum determinancy and is substituted for "max
turns" in the formula for computing the SSI. The smallest ratio
represents the path(s) with minimum determinancy and is substituted
for "min turns" in the SSI computation formula. In the same fashion,
the ratio for the trip under study is substituted for "turns in trip".

Relevant data for comparing the routes in Figures 3-28 and 3-29
are displayed in Table 3-16. Here, it is seen that the hypothetical
route in Figure 3.28 has a CRI value (-0.4243) which is a bit more
negative (and more "free") than the route in Figure 3-29 which has
a CRI value of -0.1010. To review, maximum determinancy is indicated
by a positive CRI value of 0.7071 whereas maximum freedom (i.e., mini-
mum determinancy) is indicated by a negative CRI value of -0.7071.

Limitations to the Choice Ratio Index

The same limitations apply here that apply to the Spatial
Structure Index. The CRI is meaningful only when computed for routes
effected in complex networks.

Summary

The preceding sections provide the analyst with a set of concepts
and terms to use when making inquiries concerning the route structure
and choice behavior of pedestrians engaged in making trips from one
point to another. In summary, trip networks may be defined as linear,
split, or complex. Routes within these networks may be described
### Table 3-16: Data for Example Calculations of Choice Ratio Index

**From Figure 3-28**

<table>
<thead>
<tr>
<th>Path</th>
<th>Closed/Open Node Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Determinancy Path</td>
<td>5:3 (= 1.6667)</td>
</tr>
<tr>
<td>Minimum Determinancy Path</td>
<td>2:6 (= 0.3333)</td>
</tr>
<tr>
<td>Hypothetical Path</td>
<td>3:5 (= 0.6000)</td>
</tr>
</tbody>
</table>

Computed CRI for Hypothetical Trip = -0.4243

**From Figure 3-29**

<table>
<thead>
<tr>
<th>Path</th>
<th>Closed/Open Node Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Determinancy Path</td>
<td>5:3 (= 1.6667)</td>
</tr>
<tr>
<td>Minimum Determinancy Path</td>
<td>3:6 (= 0.5000)</td>
</tr>
<tr>
<td>Hypothetical Path</td>
<td>4:4 (= 1.0000)</td>
</tr>
</tbody>
</table>

Computed CRI for Hypothetical Trip = -0.1010
generally as linear, left- or right-handed, boundary or interior.
The routes in complex networks may be further characterized by the
Spatial Structure Index and the Choice Ratio Index. Given these
tools, the reader is invited to consider the following empirical
findings concerning trip structure and choice behavior.
Empirical Aspects of Trip Structure and Route Choice

The following analysis is based primarily on data from the three samples representing complete trips: the Primary Corroborated Sample (N=83), the School Children Sample (N=50) and the Accurate Directions Sample (n=78). The relatively small size of these samples sometimes limits the sophistication of the analysis. At the same time, however, these data represent many hours of observation, interviewing, transcription, and coding. The data are "hard won" and form the first available, representative, observationally-corroborated data on route selection by pedestrians. Thus, despite the limits of the data, their analysis permits empirically-grounded inquiries which were not possible prior to the completion of this project.

The Primary Strategy: Distance Minimization

Every trip save one (made by a school child) in the three samples featured in this section (a total of 211 cases) followed a shortest distance path from start to finish. This finding demonstrates the overwhelming importance of distance minimization in path selection. Of course, those subjects in the Directions sample who gave inaccurate directions selected (by definition) something other than a least distance path to the a landmark target. It is not known, however, if these subjects would have taken the same route had they actually been engaged in walking to the landmark target themselves rather than giving directions to someone else. If actually walking, such subjects
might well have utilized various environmental clues to correct their paths en route. Additionally, they might have verified the location of the target before starting out if they felt any uncertainty about the target's location. Given more accurate information, these subjects might also choose to follow least distance paths.

The subjects who were part of the Primary Sample, but were not included in the Primary Corroborated Sample, comprise a set of 117 cases of ethologically-observed terminal trip segments. Within this set of observations, only two subjects were observed to take longer than necessary routes to reach their eventual destinations. If one considers the entire set of 250 ethologically-observed trips (the Primary Sample and School Children Sample combined), one finds that only three subjects (1.2%) did not adopt a shortest distance strategy. It is possible that these three subjects were "lost" or that they were guided by some other "primary" strategy. In summary, however, subjects almost universally followed least distance paths regardless of age, gender, trip purpose, environment, length of trip, etc.

The above finding suggests that the subjects knew their routes and destinations well. Subjects in the Primary Corroborated Sample were asked if they knew the location of their destination before starting their trips. The overwhelming majority (95%) responded that they knew exactly where their eventual destinations were located. The shortest distance route-following pattern lends support to their responses, since without knowing the location of their destinations in advance it is not likely that such a high percentage of subjects
would have been observed to follow shortest distance paths. It appears that the subjects' mental maps and/or route-finding skills were clearly adequate for the task of selecting and following shortest distance routes from place to place within the study area.

Despite nearly universal path-following behavior consistent with the distance minimization strategy, this strategy is not necessarily foremost in the pedestrian's mind. Only 53% of the Primary Corroborated Sample indicated that "directness" was a reason for choosing their routes. Interestingly, however, "directness" is possibly linked to the type of network within which a given trip is effected. Whereas 65% of those taking trips in linear networks gave "directness" as a reason for route choice, only 38% of those walking in split or complex networks cited "directness" as a factor in route selection even though they were still choosing distance minimizing paths. While this difference in referencing "directness" is not statistically significant at the .01 level, significance is very closely approached. Further, while only 26% of those taking linear trips cited reasons other than "directness" as factors in route choice, 62% of those walking in split or complex networks did cite "other" reasons (and this difference is statistically significant at the .01 level). It is concluded here that the major, controlling factor in route selection is distance minimization although the pedestrian may not be fully reflective on the issue. When given more than one shortest route alternative (as in split and complex networks), subjects must choose from the alternatives and may, therefore, focus on this secondary decision. Although
pedestrians may not fully realize that they are restricting themselves to least distance routes, their ethologically-observed behavior clearly shows such self-restriction to be nearly universal. Further, distance minimization was universal for all subjects in the Accurate Directions Sample. Pedestrians not only walk shortest distance paths themselves, they also give distance-conserving directions to others.

**Linear Trips**

Linear trips are a common pedestrian experience. 64% of all trips in the Primary Corroborated Sample and 62% in the School Children Sample were linear trips. Relatively speaking, the decision complexity of such trips is not particularly high. When there is only one shortest distance path between an origin and a destination and the pedestrian adheres to a distance minimizing strategy, then route choice becomes fixed.

The above finding suggests that the variety of route possibilities available to the majority of pedestrians is decidedly limited. Interestingly, however, the frequency of linear trips in the Asking Directions Sample is strikingly less. Only 30% of the Accurate Directions trips were "forced" by geometry into linear trips. Subjects who were asked to give directions to nearby elementary schools were confronted with a much wider range of route possibilities.

Inasmuch as subjects in the Accurate Directions Sample were "given" their "destinations" by the researcher while subjects in the
School Children Sample and the Primary Corroborated Sample selected their own destinations, it could be thought that people who actually walk might avoid taking trips in split and complex networks. An alternative explanation lies in the statistical composition of the samples, however. Despite the fact that the mean trip length of trips in the Primary Corroborated Sample (.52 mile) and the Accurate Directions Sample (.47) is not significantly different at the .01 level, the samples are not fully comparable. The distribution of trip length in the Primary Corroborated Sample is positively skewed (coefficient of skewness 1.38), indicating that the sample contains many shorter trips and a few, but much longer trips which affect the mean. The coefficient of skewness is significant at the .01 level. The distribution of trip length in the Accurate Directions Sample is also positively skewed, but to a much less extent (coefficient of skewness 0.103) and the coefficient is not significant at the .01 level. The "real life" trips in the Primary Corroborated Sample tend toward the "short" side and, since shorter trips tend to be linear trips, the higher proportion of linear trips in the Primary Corroborated Sample is explained. Trip length in the School Children Sample is also positively skewed (coefficient of skewness 0.627) but the coefficient is not significant at the .01 level. Since the mean length of trips in the School Children Sample (.36 mile) is significantly shorter than the mean for the Accurate Directions Sample, the observation that shorter trips tend to be linear helps to account for the higher proportion of linear trips in
the School Children Sample.

In the interest of exploring all possible avenues, it should be noted that no association was found between trip type and destination type. The most frequent destinations in the Primary Corroborated Sample were residential (52%), Commercial/Industrial (28%), and Public (15%) which together account for 95% of the destinations tabulated. In order to meet the requirements for a Chi-square test, trip types were collapsed into linear and non-linear (combining split and complex trips). There was no statistically significant difference between trip types across destination types at the .01 level.

Further, trip type was not associated with purpose of trip. Three purpose categories account for 80% of all trips in the Primary Corroborated Sample: shopping (30%), visiting/exercise (30%), and journey-to-work (20%). Chi-square analysis showed no significant difference between proportions of linear vs. non-linear trips associated with each purpose category (alpha set at .01).

Sex and age factors might also be thought to be associated with trip type, but a routine examination using Chi-square revealed no significant association between either of these two variables and network type (linear vs. non-linear) at the .01 level. In sum, one is left with the conclusion that the high proportion of linear trips in the Primary Corroborated Sample and the School Children Sample results from the geometry of the environment combined with the fact that many people take relatively short trips. From the data collected here it is not possible to infer that pedestrians prefer linear trips.
or avoid non-linear (split or complex) trips.

**Split Trips**

Split trips are relatively infrequent in the experience of most pedestrians. They comprise only 7% of the Primary Corroborated Sample, 16% of the School Children Sample, and 10% of the Accurate Directions Sample. Combined, these trips represent only 22 cases, a fact which severely limits the analysis of the characteristics of split trips. Inasmuch as the major aspect of split trips is whether they may be described as "left" or "right", the data for split trips are combined with the data on boundary trips (which may also be described as "left" and "right") in complex networks for the purpose of asking if the pedestrians in this study exhibited a preference of left-oriented vs. right-oriented paths.

Relevant data are presented in Table 3-17. In this table, data for split trips and boundary trips in complex networks have been combined, providing 20 cases for the Primary Corroborated Sample, 16 cases for the School Children Sample, and 48 cases for the Accurate Directions Sample. Inspection of the table reveals that the proportion of right-oriented (or "right-handed") trips is approximately 60% and the proportion of left-oriented trips is approximately 40% regardless of sample. Chi-square analysis shows that there are no significant differences in these proportions between samples with alpha set at .01.
Table 3-17: Right/Left Orientation for Split Trips and Boundary Routes in Three Samples

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Primary Corroborated Sample</th>
<th>School Children Sample</th>
<th>Accurate Directions Sample</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>12 (60%)</td>
<td>10 (62%)</td>
<td>28 (58%)</td>
<td>50 (60%)</td>
</tr>
<tr>
<td>Left</td>
<td>8 (40%)</td>
<td>6 (38%)</td>
<td>20 (42%)</td>
<td>34 (40%)</td>
</tr>
<tr>
<td>Totals</td>
<td>20 (100%)</td>
<td>16 (100%)</td>
<td>48 (100%)</td>
<td>84 (100%)</td>
</tr>
</tbody>
</table>
Given the small n-sizes for each of the three samples and the finding of no significant difference in proportions of right/left orientation between samples, all three samples are combined in order to examine the relationship between right/left orientation and gender. The relevant data are presented in Table 3-18. Chi-square showed no significant difference in right/left orientation between males and females with alpha set at .01. Table 3-19 presents data on right/left orientation by age group, but expected cell frequencies are below that required to permit Chi-square analysis of the data.

Reference personnel and reference works at the University of Nebraska-Lincoln Love Library were consulted for the purpose of providing an estimate of proportions of left vs. right orientation in the general population. Estimates of left-handedness ranged from as low as 10% of the population to as high as 50%. No firm statistics were available. The common consensus is that left-handedness is in the minority, a belief which is consistent with the figures in Table 3-17. Interestingly, a study by Brigden (1935) on blindfolded pedestrians showed that although pedestrians tend to follow a spiral path when walking while blindfolded, they demonstrated no marked tendency to spiral more to the right than to the left.
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Page 221 is lacking in number only.

No text is missing.

The complete text continues on the following page.
Table 3-18: Right/Left Orientation by Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Left</th>
<th>Right</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>15 (38%)</td>
<td>25 (62%)</td>
<td>40 (100%)</td>
</tr>
<tr>
<td>Male</td>
<td>19 (43%)</td>
<td>25 (57%)</td>
<td>57 (100%)</td>
</tr>
</tbody>
</table>

Table 3-19: Right/Left Orientation by Age Group

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Left</th>
<th>Right</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-21</td>
<td>14 (50%)</td>
<td>14 (50%)</td>
<td>28 (100%)</td>
</tr>
<tr>
<td>22-61</td>
<td>18 (40%)</td>
<td>27 (60%)</td>
<td>45 (100%)</td>
</tr>
<tr>
<td>62+</td>
<td>2 (18%)</td>
<td>9 (82%)</td>
<td>11 (100%)</td>
</tr>
</tbody>
</table>
Complex Trips

Pedestrians walking to destinations in urban environments in the study area have more opportunities to effect complex trips than to effect split trips. Although complex trips are somewhat less frequent than linear trips, complex trips are usually of much greater length. Complex trips represent 29% (N=24) of all trips in the Primary Corroborated Sample and 22% (N=12) in the School Children Sample. 60% (N=47) of the Accurate Directions Sample were confronted with the task of giving directions which necessitated describing a complex trip to the researcher/interviewer. As noted above, complex trips may be classified as either boundary trips or interior trips. The intricacies of complex trips may be further characterized using the Spatial Structure Index and the Choice Ratio Index.

Interior Routes and Boundary Routes

Table 3-20 demonstrates that boundary routes outnumber interior routes regardless of the sample referenced. Although the majority of all trips in each sample are boundary routes, the proportion of boundary routes is not equal from sample to sample. Temporarily deleting the School Children Sample (due to its small size), the boundary vs. interior proportions in the Primary Corroborated Sample and the Accurate Directions Sample were compared. Chi-square analysis revealed no significant difference in these proportions at the .01 level (although significance was very closely approached). Collapsing
<table>
<thead>
<tr>
<th>Complex Route Type</th>
<th>Sample</th>
<th>Primary Corroborated Sample</th>
<th>School Children Sample</th>
<th>Accurate Directions Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary</td>
<td></td>
<td>14 (58%)</td>
<td>9 (75%)</td>
<td>40 (85%)</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td>10 (42%)</td>
<td>3 (25%)</td>
<td>7 (15%)</td>
</tr>
<tr>
<td>Combined</td>
<td></td>
<td>24 (100%)</td>
<td>12 (100%)</td>
<td>47 (100%)</td>
</tr>
</tbody>
</table>
the School Children Sample with the Primary Corroborated Sample (on the logic that both samples represent actual walking trips rather than the "conceptual" trips found in the Accurate Directions Sample), gives very similar Chi-square results. Nonetheless, the 85% (N=40) utilization of boundary routes by subjects in the Accurate Directions Sample is quite striking.

Gender comparisons are shown in Table 3-21. In all cases except one (females in the Primary Corroborated Sample), both males and females selected boundary routes more frequently than interior routes. The small sample sizes (and resulting small expected cell frequencies for some cells) prohibits statistical analysis of the individual samples. Inspection of the table, however, gives no compelling reason to suspect that women might choose boundary routes any more frequently than men (or *vice versa*).

Analysis by age group brings similar results. Small sample sizes prevent tabular analysis and inspection of the available data shows no marked tendency for members of any particular age group to choose boundary routes any more frequently than members of any other age group.

In sum, boundary routes were selected more frequently than interior routes. Inasmuch as boundary routes tend to have fewer turns in them, this finding suggests a general tendency toward "simple" rather than "complicated" paths. This trend is especially marked in the Accurate Directions Sample where 85% of all "trips" were boundary routes. Analysis in a previous section revealed that when subjects
Table 3-21: Frequency of Boundary vs. Interior Routes by Gender

<table>
<thead>
<tr>
<th>Complex Route Type</th>
<th>Gender</th>
<th>Boundary</th>
<th>Interior</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Corroborated Sample</strong></td>
<td>Male</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td><strong>Accurate Directions Sample</strong></td>
<td>Male</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td><strong>School Children Sample</strong></td>
<td>Male</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>
in all three samples choose a split or boundary path, that choice
tends to be "right-handed" more frequently than "left-handed".

Indices of Spatial Structure and Choice for Complex Routes

Utilization of the Spatial Structure Index and the Choice Ratio
Index permits a more detailed investigation of the structural differ­
ces between boundary and interior routes. Spatial structure is con­
sidered first (Table 3-22). Recalling that the most negative SSI
represents the most simple path structure, note that boundary routes
are more "simple" than interior routes in the Primary Corroborated
Sample and the School Children Sample. These differences are marked
in the Primary Corroborated Sample (where statistical significance at
the .01 level is very closely approached) and in the School Children
Sample (wherein statistical significance is reached at the .01 level,
but the small sample size [N=12] must also be kept in mind). The
spatial complexity of boundary and interior routes in the Accurate
Directions Sample is essentially equal. In this sample, both types
of routes are relatively simple. Even when subjects in this sample
responded with interior routes, they managed to find relatively simple
ones.

Interior and boundary routes also differ on the Choice Ratio
Index (Table 3-23). Recall that the most negative value is the most
"free", whereas the most positive value is the most "determined".
Regardless of sample, boundary routes are more "determined" than the
Table 3-22: Mean SSI for Boundary and Interior Routes by Sample

<table>
<thead>
<tr>
<th>Complex Route Type</th>
<th>Primary Corrobrated Sample</th>
<th>School Children Sample</th>
<th>Accurate Directions Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary</td>
<td>-.438 (N=14)</td>
<td>-.314 (N=9)</td>
<td>-.471 (N=40)</td>
</tr>
<tr>
<td>Interior</td>
<td>-.047 (N=10)</td>
<td>+.707 (N=3)</td>
<td>-.473 (N=7)</td>
</tr>
<tr>
<td>Combined</td>
<td>-.275 (N=24)</td>
<td>-.059 (N=12)</td>
<td>-.472 (N=47)</td>
</tr>
</tbody>
</table>

Interpretive note: Negative values indicate relatively simple routes, positive values indicate relatively complex routes.
Table 3-23: Mean CRI for Boundary and Interior Routes by Sample

<table>
<thead>
<tr>
<th>Complex Route Type</th>
<th>Primary Corroborated Sample</th>
<th>School Children Sample</th>
<th>Accurate Directions Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary</td>
<td>+.109 (N=14)</td>
<td>-.157 (N=9)</td>
<td>+.315 (N=40)</td>
</tr>
<tr>
<td>Interior</td>
<td>-.524 (N=10)</td>
<td>-.354 (N=3)</td>
<td>-.296 (N=7)</td>
</tr>
<tr>
<td>Combined</td>
<td>-.154 (N=24)</td>
<td>-.206 (N=12)</td>
<td>+.224 (N=47)</td>
</tr>
</tbody>
</table>

Interpretive note: Negative values indicate increasing freedom of choice, positive values indicate relatively more determination and lack of choice.
interior paths. This follows from the fact that while boundary routes start off with a series of open nodes, they quickly join-up with absorbing boundaries filled with closed nodes. It is an interior route which, generally speaking, preserves a pedestrian's choice options.

The Relationship of SSI to CRI

Since interior routes tend to be more complex and less determined than boundary routes, it might be suspected that SSI and CRI values are mirror images of each other. For example, in order to follow a structurally simple path, one surrenders a degree of choice freedom while en route. Conversely, in order to preserve choice options, a pedestrian must generally forego the conceptual simplicity of a structurally simple route. Nonetheless, correlations \( r^2 \) between the indices are generally mild and in no case are they statistically significant at the .01 level (Table 3-24).

These two indices are here conceptualized as representing dual aspects of route selection which may, for some pedestrians, exist in dynamic tension with each other. These potentially competing demands on pedestrian decision-making can be "balanced" by the pedestrian such that a little bit of route simplicity is "given up" in the interest of gaining a much greater degree of choice freedom (and vice versa). To the extent that pedestrians may attempt to "have their cake and eat it too" (e.g., by discovering a maximally simple freedom-preserving path), a degree of empirical "slippage" argues against any tight,
Table 3-24: Correlations ($r^2$) between SSI and CRI by Sample

<table>
<thead>
<tr>
<th>Sample</th>
<th>SSI with CRI ($r^2$)</th>
<th>N-Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Corroborated Sample</td>
<td>.00</td>
<td>24</td>
</tr>
<tr>
<td>School Children Sample</td>
<td>.25</td>
<td>12</td>
</tr>
<tr>
<td>Accurate Directions Sample</td>
<td>.04</td>
<td>47</td>
</tr>
</tbody>
</table>

Note: None of the correlations are significant at the .01 level.
logical conceptualization of SSI and CRI as two sides of the same coin. While such a conception is sound in its outlines, the correlation analysis completed above requires this theorist to posit the relationship between SSI and CRI as a flexible one in which the potential tension between spatial simplicity and freedom of choice is often subtly side-stepped by the pedestrian.

**Spatial Structure and Choice Ratios for Samples as Wholes**

Attention is now focused on the spatial structures within each sample as a whole. The most simple paths were observed, on average, in the Accurate Directions Sample ($SSI = -0.472$). The most complex paths, on average, were found in the School Children Sample ($SSI = -0.059$). The mean for the Primary Corroborated Sample fell in between ($SSI = -0.275$). Analysis of variance shows these difference to be significant at the .01 level. The relative magnitude of these values is as predicted in the hypotheses outlined near the end of Chapter One.

It was hypothesized that persons giving directions would choose structurally simple routes, perhaps because they feel such routes are more easily remembered and followed or because giving "simple" instructions reduces interaction time between interviewer and direction giver. It was also predicted that people who actually walk would select somewhat more complex paths relative to those provided by direction givers. It was suggested that pedestrians actually prefer
something more than minimal simplicity in their routes. Finally, it was hypothesized that young, elementary school children who are still learning about their environments would select somewhat more complex paths than their elders. This prediction was founded on the thesis of effectance which holds that exploratory behavior is necessary to gain mastery and competence in a given environment. It was then reasoned that selecting complex routes is a form of exploratory behavior. The data collected for this study are consistent with all three hypotheses.

Data on Choice Ratios provide an alternate look at the same questions. The mean CRI for the Accurate Directions Sample (CRI = .224) is the most "determined" of all three samples. Interestingly, the most "free" mean value was logged by the Primary Corroborated Sample (CRI = -.154). The School Children Sample CRI mean was -.2061. Although school children tend to take the most complex routes, they apparently do not avoid becoming "trapped" in absorbing boundaries as often as they might. Perhaps this is something which is learned with experience and reflected in the Primary Corroborated Sample. Analysis of variance shows the differences between sample means to be statistically significant at the .01 level.

*Structure, Choice, and Gender*

Gender differences on the Spatial Structure Index are reported by sample in Table 3-25. It was hypothesized that women who walk
Table 3-25: Mean SSI for Males and Females by Sample

<table>
<thead>
<tr>
<th>Gender</th>
<th>Primary Corroborated Sample</th>
<th>School Children Sample</th>
<th>Accurate Directions Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>-.523 (N=10)</td>
<td>+.141 (N=5)</td>
<td>-.447 (N=28)</td>
</tr>
<tr>
<td>Females</td>
<td>-.097 (N=14)</td>
<td>-.202 (N=7)</td>
<td>-.509 (N=19)</td>
</tr>
<tr>
<td>Combined</td>
<td>-.275 (N=24)</td>
<td>-.059 (N=12)</td>
<td>-.472 (N=47)</td>
</tr>
</tbody>
</table>

Interpretive note: Negative values indicate relatively simple routes, positive values indicate relatively complex routes.
(represented in the Primary Corroborated Sample) would select slightly less complex paths than men. The very opposite was discovered. Women in the Primary Corroborated Sample selected much more complex paths than men and this difference is statistically significant at the .01 level.

Comparison between the Primary Corroborated Sample and the Accurate Directions Sample is particularly instructive. Men not only give spatially simple instructions, they also select relatively simple paths when walking themselves. Women, on the other hand, not only give even more simple directions, they select far more complex paths when actually walking. Methodologically, it should be noted that women in the Accurate Directions Sample were giving directions to a male interviewer. This may have been a reactive aspect of the study. Is it possible that women feel they need to give simple, easy to understand instructions to men? In any event, one wonders if women, who actually select much more complex paths for themselves when walking, would give somewhat more complex directions to a female interviewer.

A curious reversal is observed in the School Children Sample. Here, boys effect relatively complex routes while girls follow more simple ones. The sample size is too small for a conclusive argument, but the trend suggests that women, as they grow older, select increasingly more complex routes whereas males "lose interest" in spatially complex routes.

Inspection of Table 3-26 reveals that women tend to preserve
<table>
<thead>
<tr>
<th>Gender</th>
<th>Primary Corroborated Sample</th>
<th>School Children Sample</th>
<th>Accurate Directions Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>-.018 (N=10)</td>
<td>-.566 (N=5)</td>
<td>+.336 (N=28)</td>
</tr>
<tr>
<td>Females</td>
<td>-.252 (N=14)</td>
<td>+.051 (N=7)</td>
<td>+.060 (N=19)</td>
</tr>
<tr>
<td>Combined</td>
<td>-.154 (N=24)</td>
<td>-.206 (N=12)</td>
<td>+.224 (N=47)</td>
</tr>
</tbody>
</table>

Interpretive note: Negative values indicate increasing freedom of choice, positive values indicate relatively more determination and lack of choice.
freedom of choice both when giving directions (even though giving spatially simple instructions!) and when walking themselves. As with the SSI, the CRI patterns for men and women are reversed in the Primary Corroborated Sample and the School Children Sample. Young girls tend to take much more determined paths than they do in later life. Males, on the other hand, choose relatively "free" paths as youths, but not as adults. The differences between males and females in the School Children Sample are not statistically significant at the .01 level, however.

Structure, Choice, and Age

Data on age group association with spatial complexity and freedom of choice were very unstable from sample to sample. Small expected cell frequencies prohibited tabular analysis. In lieu of a tabular data presentation, suffice it to say that correlations between age group membership in the Primary Corroborated Sample and the Accurate Directions Sample and SSI and CRI were not large. The largest $r^2$ was .03 for SSI with age group in the Primary Corroborated Sample. The smallest $r^2$ was .00 for CRI with age group in the Accurate Directions Sample. No correlation was statistically significant at the .01 level in any case.

Structural Simplicity and "Directness"

Interestingly, subjects in the Primary Corroborated Sample who,
in giving a reason for route choice, cited "directness" as a motive, took slightly simpler routes (SSI = -.283) than those who cited some "other" reason (SSI = -.147). This difference is not statistically significant at the .01 level, however. Yet, the trend is of interest because it suggests the possibility that "directness" is understood to be some function of route simplicity rather than physical length.

Environmental Factors—Temperature

Observations and interviews were completed during relatively hot, summer weather for the most part. Yet, a fairly wide range of temperatures was recorded. For the Primary Corroborated Sample, the highest temperature was 95° F. The minimum was 66° and the mean was 83°. For the Accurate Directions Sample, the maximum was 99°, the minimum was 82°, and the mean was 92°. The weather during the observations of school children was somewhat cooler. The maximum was 89°, the minimum was 43°, and the mean was 73°. Since such factors as "shade seeking" during hot, sunny days might affect route choice, correlations were run between temperature and SSI and CRI. The results are presented in Table 3-27. In no case was a strong relationship observed and in no case are the correlations statistically significant at the .01 level. While environmental factors may well influence route choices, temperature did not appear to be an important factor in this study.
Table 3-27: Correlations ($r^2$) between Temperature, Trip Length and SSI, CRI by Sample

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Primary Corroborated Sample</th>
<th>School Children Sample</th>
<th>Accurate Directions Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature x SSI</td>
<td>.03 (N=24)</td>
<td>.04 (N=12)</td>
<td>.07 (N=47)</td>
</tr>
<tr>
<td>Temperature x CRI</td>
<td>.13 (N=24)</td>
<td>.13 (N=12)</td>
<td>.00 (N=47)</td>
</tr>
<tr>
<td>Trip Length x SSI</td>
<td>.00 (N=24)</td>
<td>.12 (N=12)</td>
<td>.01 (N=47)</td>
</tr>
<tr>
<td>Trip Length x CCI</td>
<td>.03 (N=24)</td>
<td>.00 (N=12)</td>
<td>.05 (N=47)</td>
</tr>
</tbody>
</table>

Note: None of the above correlations are significant at the .01 level.
Effects of Trip Length on CRI and SSI: A Note

Since it was observed in a preceding section that network complexity tends to increase with network length, it is useful to demonstrate empirically that the SSI and CRI, being standardized measures, are independent of trip length. Table 3-27 reports correlations ($r^2$) between trip length on the one hand and CRI and SSI on the other. In no case is the relationship particularly strong. None of the correlations approach statistical significance at the .01 level. It is concluded that SSI and CRI values are essentially independent of trip length.

Concluding Note

A general overview of the findings reported above is reserved for the concluding chapter. A fundamental point must be recalled, however, to keep this review in proper perspective: the findings reported above are based on relatively small samples. As a result, the insights generated by the data and analyses in this study must, at best, be regarded as suggestive rather than definitive.
This study began with a hierarchically-organized review of the pedestrian's basic spatial skills: walking, crossing streets, and choosing routes. The act of walking was presented as a common, ordinary, deceptively simple human activity. The "rules" of walking are subtle, highly patterned, and universally socialized without much conscious reflection within every cultural group.

A major purpose of this study was the "uncovering" of pedestrians' rules for choosing and describing routes. The search for these rules was set within a game strategic framework in which each trip was conceptualized as a "game". As such, the researcher was interested in the strategies employed by pedestrians for "winning" their games, that is, for successfully getting from one place to another on an
urban "gameboard" composed of a maze of passageways connecting origins and destinations. It is not obvious to this researcher, however, that pedestrians are at all consciously aware of the strategies they employ (unlike the calculating Mr Spock of Star Trek fame, see Figure 4-1). This state of "unreflectiveness" applies not only to route-selection strategies but also to such processes as "scanning", the exchange of cues when pedestrians approach each other, the assignment of "watching roles" at urban intersections, etc.

If pedestrians do use various strategies in route selection, this researcher is convinced that they are largely applied without conscious reflection. When subjects were asked to provide reasons for their route choices, many responded with some variation on "directness" as a factor in route choice. This primary strategy, distance minimization, was observed over and over again. It is essentially a universal strategy. Although in reduced numbers, many subjects still cited "directness" as a reason for route choice even when they were choosing between two or more alternative routes of the same length. The concept of "directness" itself may well be associated in the subject's mind with some function of simplicity vs. complexity rather than with physical distance per se. Hence, even when subjects report "directness" as a reason for route choice, it is not at all clear that they are necessarily aware that they are minimizing distance as a primary strategy in route choice. Whatever the case, pedestrian's self-understanding of their route selection patterns does not appear particularly deep.
Figure 4-1: Mr Spock Uses a Simple Binary Strategy

Source: Des Moines Register, February 15, 1981.
When subjects responded with "other" reasons for route choice it was almost always in terms of physical, environmental attributes such as, "It's a nice way to walk", "The 7-11 is on the way", or "The park is so pretty". Issues of imageability, simplicity, complexity, choice, freedom, etc., were never raised by the pedestrians themselves. Thus, one may question whether the "strategic" framework advanced in this study is experientially relevant to the pedestrian in the street.

Theoretically, on the other hand, the strategic orientation is reasonably fruitful. The strategy framework adopted in this study was derived from existing literature. The pioneering work of Dietrich Garbrecht deserves very special mention. The more general, but centrally important man-environment theories of Amos Rapoport must also be cited. Based on the content of published research, a series of hypotheses were presented to the reader:

First, that pedestrians would choose shortest paths whatever else they might do. This was demonstrated to be nearly universally true for the subjects in this study.

Second, that pedestrians giving directions to someone else would choose to describe relatively simple routes. This was clearly shown to be the case. Pedestrians described simple boundary routes as well as simple interior routes. The simple spatial structure of these routes was confirmed through analysis of SSI scores for the proffered directions.

Third, that young pedestrians would select relatively more complex
routes in an effort to explore, comprehend, and gain mastery over their environments. Analysis of SSI scores revealed that elementary school children as a group took much more complex routes than their adult counterparts.

Fourth, that adult pedestrians would seek more complexity in their own routes than was manifested in the routes that subjects proffer when asked for directions to a target landmark. Again, analysis of SSI scores demonstrated this to be the case.

Fifth, it was hypothesized that women would select less complex routes than men. Analysis of SSI scores revealed just the opposite. The original hypothesis was based on the notion that women had less spatial experience, that they were more often passive passengers. The data show this is clearly not an accurate description of women in the pedestrian mode. Women were found "in the streets" in larger numbers than their proportion in the general population would warrant. Further, women frequently make very lengthy pedestrian trips. Women are experienced, knowledgeable pedestrians. Given these findings, it is not now surprising to find the reverse of that which had been hypothesized.

Thus, the theoretical fruitfulness of the strategy framework is clear. But, again, the relevance of this approach for understanding the experiences of pedestrians remains open. It is suggested here that exploration of this question will best be accomplished through a qualitative approach, such as adopted by David Seamon in his phenomenological study of the geographical life-world.
Methodologically, the study revealed for the first time that relatively reliable route descriptions can be obtained by the use of questionnaires. This is a definite boon for further studies of routes and route-selection. The high cost (especially in time) of ethological tracking results in small sample sizes, as was the case in this study. The small sample size hampered the depth and definitiveness of the analysis. It was not possible, for example, to further investigate the two route selection strategies proposed by Dietrich Garbrecht (i.e., random path and random walk) because the data provided only 13 cases which could have been analyzed using the technique developed by the present author in a previous study. For reasons such as this, it is a definite advantage to know that questionnaires can be used with relative confidence in future studies.

Yet, even armed with good questionnaires, researchers need to concentrate their research on people who actually walk as a usual or frequent mode of travel. As a class, this group is not well-understood nor well-characterized. The need for a focus on the macro-sociology of walking was also noted above and is reiterated here. This author feels confident that future insights in these and other areas will be forthcoming in the not too distant future. The last 15 years has witnessed a virtual "explosion" of interest in and research on the pedestrian and his/her world. Where there were barely any published researches on pedestrians a decade ago, there are now several bibliographies with literally hundreds of entries on pedestrian-related
issues. It is hoped that the conceptualizations, measures, techniques, and findings developed and reported in this study will be useful to others in furthering our new, but ever deepening understanding of the pedestrian.
APPENDIX

Location of Interception Points

The following information on the location of interception points (street intersections) used as sample points in this study is provided for the purpose of documenting the details required for replication and/or extension of this study.

<table>
<thead>
<tr>
<th>Quadrat</th>
<th>Interception Point Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10th and D Streets</td>
</tr>
<tr>
<td></td>
<td>13th and C Streets</td>
</tr>
<tr>
<td></td>
<td>11th and Washington</td>
</tr>
<tr>
<td></td>
<td>10th and E Streets</td>
</tr>
<tr>
<td></td>
<td>11th and F Streets</td>
</tr>
<tr>
<td>2</td>
<td>14th and Plum</td>
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<tr>
<td></td>
<td>17th and Harwood</td>
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<tr>
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<td>18th and Harwood</td>
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<tr>
<td></td>
<td>15th and South</td>
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<tr>
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<td>16th and Euclid</td>
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<tr>
<td>3</td>
<td>14th and H Streets</td>
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<tr>
<td></td>
<td>12th and E Streets</td>
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<td>15th and E Streets</td>
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<td>Woodsdale and Summit</td>
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<td>Stratford and Rathbone</td>
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<td></td>
<td>31st and Georgian Court</td>
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<td>29th and Jackson Drive</td>
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<td>6</td>
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<td>26th and Garfield</td>
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<td>27th and Summer</td>
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