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Transportation and Well-Being

AN ECOLOGICAL PERSPECTIVE

DANIEL STOKOLS and RAYMOND W. NOVACO

INTRODUCTION

In large metropolitan areas of the United States, the work day routinely begins with a monumental traffic jam. Traffic congestion prevails in America primarily because commuters prefer to travel to and from work by private automobile (cf. Aangeenbrug, 1965; Catanese, 1972). In 1970, approximately 66% of the American labor force traveled to work by private car (Federal Highway Administration, 1977). Within certain metropolitan areas (e.g., Atlanta, Dallas, Detroit, Los Angeles, and Orange County, California), the proportion of automobile commuters ranged from 85% to 93%. Despite the recent surge and projected increases in the cost of fuel, the proportion of automobile commuters in the national work force is expected to be about 73% by 1990 (cf. Kain, Fauth, & Zax, 1977).

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What are the costs of our dependence on the automobile as a means of traveling to work? What are the relative costs of alternative travel modes? What conditions associated with transportation may have negative effects on well-being? The costs and benefits of environmental conditions and social programs typically are gauged by their immediate and economically tangible outcomes (cf. Catalano, 1979). When considering alternative modes of travel, individual commuters generally focus on the relative monetary expense, time constraints, and opportunities for privacy associated with the various modes. Government agencies tend to emphasize factors such as community levels of air pollution and fuel consumption (cf. Hartgen, 1977; Horowitz & Sheth, 1976). This emphasis on the economic and environmental consequences of personal and community travel patterns neglects a potentially important set of transportation-related outcomes, namely, the cumulative emotional, behavioral, and health consequences of travel conditions. These outcomes, while less immediate and tangible than monetary and time constraints and less conspicuous than environmental decay, nevertheless should be considered in any attempt to assess the impact of transportation environments on people.

Identifying the previously neglected impacts of transportation on health and behavior is a matter of practical as well as theoretical significance; for if the prevalence and severity of such impacts are demonstrated empirically, then a number of ameliorative strategies might be devised and implemented by transportation planners. Although research concerning the adverse behavioral and health consequences of travel conditions has been sparse, preliminary evidence suggests that these effects may be both prevalent and disruptive.

In a national survey of American workers conducted in 1977, for example, 38% of the commuters sampled reported that they experienced transportation-related problems (Quinn & Staines, 1979).[1] Among those respondents mentioning problems, about 50% cited "traffic congestion, nuisances, or inconveniences."[2] Also, 33% of the respondents characterized their travel problems as "sizable" or "great" (vs. "no problem at all," 8%, or "slight problem," 59%). In an earlier survey of Salt Lake City motorists, 12% of the men and 18% of the women sampled reported that at times, they "could gladly kill another driver" (Turner,

[1]We are grateful to Sandra Kirmeyer for bringing this survey to our attention.

[2]Twelve other categories of problems were mentioned by respondents. The second most frequently mentioned problem was "traffic dangers" (18.5%). Other problems cited were "travel expense" (4%), "lack of parking space" (2.5%), and "inconvenient public transit schedules" (2.1%). The least frequently mentioned category was "worker's transportation inconveniences his or her family" (.6%).

Layton, & Simons, 1975, p. 1100). Furthermore, field-experimental studies of automobile drivers have shown a significant relationship between exposure to rush-hour traffic and a variety of adverse physiological reactions, including chest pain and cardiac arrhythmia (cf. Aronow Harris, Isbell, Rokaw, & Imparato, 1972; Taggart, Gibbons, & Somerville, 1969).

While the above studies suggest the range of behavioral and health problems associated with travel conditions, they do not provide an integrative theoretical analysis of the multiple environmental and personal underpinnings of those problems. The major objective of this chapter is to develop a systematic theoretical framework that addresses the relationships among transportation conditions and human well-being.

In the following section of the chapter, previous research on transportation and stress is reviewed. Certain limitations of this work are noted as the basis for developing an alternative conceptual and methodological approach. The next section outlines the prerequisites for an ecological analysis of transportation and well-being, and it identifies the key assumptions underlying our theoretical approach. Specifically, our analysis portrays certain conditions of transportation (e.g., traffic congestion) as environmental demands that tax the individual's adaptive capacity. The emotional, behavioral, and health consequences of these demands are assumed to be jointly determined by a complex array of circumstances existing within various domains of the individual's life situation (i.e., within one's community, transportation, residential, and work environments).

In the final section of the chapter, a longitudinal field experiment designed to assess certain predictions suggested by our analysis is summarized. The findings from the first phase of the research reveal the interactive effects of transportation conditions (e.g., length of commute, type of car) and personal attributes (e.g., residential choice, personality dispositions) on the mood, physiology, and task performance of automobile commuters. Data from the second phase of the study highlight the adaptive problems that arise in relation to commuting conditions, as well as the active efforts made by some commuters to alleviate such problems. The research and policy implications of our analysis are subsequently discussed.

PREVIOUS RESEARCH ON TRANSPORTATION AND STRESS

We will provide a selective yet representative overview of previous work concerning transportation and stress, but before examining specific studies, we will be more explicit about our principal concepts. The term *transportation* has been used to refer to diverse phenomena: the vehicle itself, alternative modes of travel, conditions within travel-related environments, and the broad network of travel facilities and services existing within a community. [3] In most research on travel conditions and traveler stress, *transportation* generally has been used to refer to the automobile mode of travel and to the immediate, intra and extravehicular conditions facing individual drivers and passengers. In a few studies, the focus has been on public transit (cf. Singer, Lundberg, & Frankenhaeuser, 1978; Taylor & Pocock, 1972) rather than on automobile travel. Our own conceptual approach does not restrict the meaning of *transportation* to automotive and/or public transit, as will become more apparent in the following section of the chapter. In the present section, however, we highlight the typical emphasis on these modes of travel in previous studies.

The term *stress* also has been associated with several diverse meanings. In general, *stress* refers to a state of imbalance within the organism that (1) is elicited by a disparity between environmental demands and the individual's capacity to cope with those demands and (2) is manifested through a variety of physiological, emotional, and behavioral responses. These responses occur as a result of the individual's exposure to excessive environmental demands, or *stressors*. Conditions of the physical environment operate as stressors to the extent that they tax or exceed the individual's adaptive resources (cf. Lazarus, 1966; Selye, 1956).

More detailed conceptualizations of stress have been developed from the medical, psychological, and sociological perspectives. From a medical perspective, stress is typically construed as a defensive bodily response to environmental demands (e.g., toxins, microbes, extreme temperature) involving specific physiological components, such as adrenal stimulation, gastrointestinal disturbances, and the shrinkage of lymphatic structures (cf. Selye, 1956, 1976). Psychological analyses place a greater emphasis on the individual's cognitive appraisal of threatening environmental conditions and personal coping resources than do medical models of stress (cf. Appley & Trumbull, 1967; Lazarus, 1966; McGrath, 1970). And sociological analyses focus on societal conditions that adversely affect the well-being of specific groups within the community (cf. Levine & Scotch, 1970; Mechanic, 1968).

The medical perspective on stress has been the predominant orienta-

[3]See, for example, the glossary of transportation-related terms provided by the Federal Highway Administration (1977, pp. 42–44).

tion reflected in earlier studies of transportation and stress. Our review of the literature is organized around two broad categories of research: (1) investigations of drivers' and passengers' reactions to conditions of automobile travel; and (2) studies of commuters' responses to conditions of public transit.[4] Following our review of this research, we develop an ecological framework which integrates psychological, sociological, and medical perspectives on transportation and stress.

Research on Automobile Travel and Stress

The impact of environmental demands on automobile travelers has been assessed through experimental studies of both simulated and actual driving situations. A wide array of environmental factors have been examined in this research, including road design, traffic conditions, and intravehicular levels of noise, heat, and air pollution.

Road Design and Traffic Conditions

A study by Michaels (1962) exemplifies the kind of field investigation that has been employed to assess the relationships among route characteristics, traffic conditions, and physiological arousal while driving (or immediately thereafter). The effects of road design and traffic volume (vehicles per hour) on drivers' tension responses were examined. Six male drivers, aged 17–22, were tested on four roads of differing design (e.g., urban freeways vs. arterial and primary streets). Each driver traveled the routes 12 times each during both off-peak and peak traffic hours. Tension reactions were assessed through continuous recording of the drivers' galvanic skin response (GSR) during each trip. Elevated levels of GSR (indicating driver tension) were found to be associated with routes characterized by minimal or partial (vs. complete) control of peripheral traffic access and with conditions of high traffic volume. These findings were explained in terms of the tension-promoting interferences associated with route intersections and congested traffic.

A number of other researchers have reported a significant, positive correlation between traffic volume (e.g., driving during rush hour) and increased levels of heart rate, blood pressure, and electrocardiogram irregularities (cf. Aronow *et al.*, 1972; Hunt & May, 1968; Simonson, Baker, Burns, Keiper, Schmitt, & Stackhouse, 1968; Taggart, Gibbons, &

[4]We are unable, in this chapter, to review the extensive literature on road hazards and traffic safety. For a review of this research and a discussion of the environmental and psychosocial determinants of traffic accidents, see Forbes (1972) and Knapper and Cropley (1978,1980).

Somerville, 1969). These cardiovascular effects are especially pronounced among drivers with coronary artery disease (i.e., those having a record of angina pain and/or myocardial infarction). But even among healthy drivers, exposure to city traffic for prolonged periods (e.g., two hours) appears to be associated with a wide range of physiological imbalances, including heightened catecholamine and adrenocortical secretion (cf. Bellet, Roman, & Kostis, 1969).

Moreover, traffic situations of high complexity (e.g., negotiating dangerous curves and motorway exchanges; passing other vehicles and sudden breaking) have been found to be associated with increased heart rate and blood pressure (cf. Littler, Honour, & Sleight, 1973; Rutley & Mace, 1970; Simonson *et al.*, 1968). The relationship between the complexity of driving tasks and increased physiological arousal suggested by these field experiments has been corroborated in a number of driving simulation studies (cf. Forbes, 1972; Heimstra, 1970). Such research also has established a significant association between the complexity of simulated driving situations and impaired performance of braking and steering tasks.

Intravehicular Conditions of Noise, Heat, and Air Pollution

Drivers' reactions to high levels of noise and heat were examined in a recent simulation study by Neumann, Romansky, and Plummer (1978). Twenty-five males, aged 18–39, were tested in a driving simulator under ambient and moderately high levels of heat and noise. Participants completed two consecutive trials in the simulator, each lasting for 2¾ hours. The room temperatures and sound levels for the two trials were 76°F and 55 decibels (dBA), and 90°F and 78dBA.

A comparison of the subjects' task performance, physiology, and mood during the two trials revealed significantly high levels of stress under conditions of increased temperature and noise. Specifically, during the second trial, the subjects exhibited response decrements on both visual and auditory tasks and manifested elevations in heart rate, GSR, systolic and diastolic blood pressure, and adrenocortical secretion. Moreover, subjective ratings of discomfort and fatigue increased during the raised-temperature-high-noise trial. Because the first and second trials were not counterbalanced, however, the possibility remains that the stress reactions observed during the latter part of the experiment were prompted partly by the sheer duration of the test session (the two trials lasting a total of 5½ hours), as well as by the heightened temperature and noise during the second trial. Furthermore, the separate effects of noise and temperature were not disentangled.

The joint effects of heat and humidity on drivers were examined in a field experiment conducted by Mackie, O'Hanlon, and McCauley (1974). The participants were 10 males and 10 females, aged 25–35, who were recruited to drive two round trips between Santa Barbara and King City, California (180 miles in each direction along U.S. 101, a four-lane divided highway). One trip was made under hot and humid conditions, while the other was completed at comfortable temperature and humidity levels (90 WBGT vs. 67 WBGT, respectively).[5] The trips, counterbalanced for order, were made one week apart. Temperature and humidity were controlled via a specially equipped heater within the experimental vehicles (two full-sized 1972 Fords). The sound level was fairly constant for all trips, ranging between 64 and 68 dBA.

A trained observer accompanied the driver during each trip. The observer occupied the rear seat and was separated from the driver by a Plexiglass divider. In addition to monitoring physiological measurement devices, the observer recorded a variety of performance and subjective-report data throughout the journey. Statistical analyses indicated significant elevations in the drivers' body temperature, systolic blood pressure, heart rate, and heart rate variability while driving under conditions of high temperature and humidity. These conditions also were associated with decreased levels of self-reported alertness and central nervous system arousal (measured via electroencephalograph readings) and decrements in driving performance (e.g., greater frequencies of technical errors such as lane drift, speeding, and tailgating).

The experiment by Mackie *et al.*, like most studies of driving and stress, employed a small sample and provided no evidence for the reliability of the observers' ratings of the drivers' performance. For the most part, however, the investigation was well designed and supported the hypothesis that prolonged exposure to heat and humidity adversely affects drivers' physiology, mood, and performance.

Air pollution is an additional environmental demand to which automobile travelers are routinely exposed. Carbon monoxide (CO) is an especially toxic pollutant produced by gasoline-powered vehicles. Intravehicular levels of CO are closely related to traffic density and speed, with the highest concentrations occurring during congested, rush-hour traffic and at busy freeway interchanges (Chaney, 1978). The maximum concentrations of CO permitted by the Federal Ambient Air Quality Standards are 9 parts per million (ppm) for 8 hours and 35 ppm for 1

[5]The WBGT index is a weighted sum of dry bulb (DB), wet bulb (WB), and globe thermometer (GT) readings. The index reflects the combined effects of air temperature, air velocity, and relative humidity.

hour. On the Los Angeles freeways, ambient levels of CO as high as 120 ppm have been recorded during rush-hour periods (Haagen-Smit, 1966).

Laboratory experiments have demonstrated that CO concentrations corresponding to those found during heavy rush-hour traffic can impair performance on visual signal-detection tasks (Horvath, Dahms, & O'Hanlon, 1971; Halperin, McFarland, Niven, & Roughton, 1959). The adverse consequences of exposure to CO while driving may be especially pronounced among individuals with coronary artery disease (CHD), according to the findings from a field experiment conducted by Aronow *et al.* (1972). In that study, each of 10 drivers who had been diagnosed as having CHD drove a designated route for 90 minutes during rush-hour traffic in Los Angeles. On a subsequent day, the participants drove the same route but breathed pure compressed air during the trip. Analyses indicated significantly higher CO in expired air and carboxyhemoglobin in the blood after those trips in which the drivers inhaled impure versus pure air. Moreover, tolerance for strenuous exercise decreased and complaints of angina pain increased following exposure to the freeway air.

Research on Public Transit and Stress

The relationship between conditions of public transit and commuter stress has received little empirical attention. Only two major investigations of these phenomena have been conducted: a survey of London office workers by Taylor and Pocock (1972), and a field-experimental study of train commuters in Stockholm conducted by Singer *et al.*, (1978; cf. Lundberg, 1976).

The London survey involved 1,677 male and 317 female employees, aged 30–69, who had worked at a large company for at least one year. Each respondent completed a travel questionnaire pertaining to various aspects of the commute to work (e.g., types of transit used, duration and unpleasantness of the trip) and to several personal and demographic factors (e.g., age, sex, job grade). These variables were cross-tabulated with company records of certified and uncertified absence from work. Certified absences were defined as those validated by a medical certificate.

Of the 1,994 respondents, 1,890 (95%) used some form of public transit in their journey between home and work (e.g., British Rail and London Transport trains, public buses). Also, the journeys of public transit commuters typically involved multiple stages (i.e., portions of the trip in which neither the mode of travel nor the vehicle was changed;

walks taking five or more minutes were counted as a separate stage). The average number of stages for the entire sample was 2.84. The duration of the journey ranged from 12 minutes to 2½ hours, with a median of 1 hour. The women had somewhat shorter journeys than the men.

The major finding of the survey was a significant correlation between the number of stages in the journey and the frequency of both certified and uncertified absences from work. Moreover, car users (412 respondents) had significantly higher rates of uncertified absence than did persons who did not use private transport. Also, the frequency and length of uncertified absences were significantly greater among those commuters whose work trips took longer than 1½ hours. Ratings of actual and perceived crowdedness of public transit facilities were not significantly correlated with either certified (e.g., influenza-related) or uncertified absence rates.

The field experiment conducted by Singer *et al.* involved 30 male commuters who traveled regularly between home and work along the Nynashamn–Stockholm train line. Participants were between 20 and 67 years of age and had commuted on the same train line for at least six months. All subjects rode a morning train. One group ($n = 15$) boarded the train at its first stop (Nynashamn) and the other ($n = 15$) boarded at a midpoint on the route (Vasterhaninge). The commuting times for the two groups were 79 and 43 minutes, respectively. Over a four-day period, the subjects made psychophysical judgments concerning traveling conditions on the train (e.g., perceived crowdedness), and on the third day, they provided urine specimens prior to leaving their homes and on arrival at the Stockholm station. The urine samples were analyzed for adrenalin and noradrenalin levels.

A comparison of the data from the two groups of commuters revealed several significant trends. First, subjective reports of crowdedness and discomfort increased as the train approached the Stockholm (terminal) station. Second, for both groups of commuters, urinary levels of adrenalin and noradrenalin were higher after the train ride than before it. But the increase in adrenalin secretion during the train ride was significantly greater among the short-commute (Vasterhaninge) than among the long-commute (Nynashamn) subjects. Also, in a follow-up study involving 17 of the same individuals, ratings of perceived crowding and adrenalin levels were found to be higher among both groups of commuters on a day when more passengers rode the train than on another when the train was occupied by fewer people (Lundberg, 1976). Thus, the findings reported by Singer *et al.* and Lundberg suggest that the duration of the journey may be a less crucial determinant of commuter stress than certain other conditions of travel, including the crowdedness and complexity of commuting situations (e.g., opportunities for choosing a seat on entering a train).

The Taylor and Pocock survey and the Singer *et al.* field experiment share certain methodological difficulties. Most importantly, variables that may covary with commuting distance (e.g., degree of residential choice, chronic exposure to midtown vs. suburban living environments) cannot be ruled out as alternative explanations for the observed associations between the duration and/or complexity of the commute and levels of commuter stress. Nonetheless, the findings from these studies taken together (and especially in light of Lundberg's findings regarding crowded vs. uncrowded trains) are important in suggesting certain objective and subjective conditions of travel (e.g., the number of stages in a journey; the perceived crowdedness of transportation environments) that may promote adverse emotional, physiological, and health consequences among commuters.

Limitations of Earlier Research on Transportation and Stress

Despite the specific methodological difficulties inherent in many of the studies discussed above (e.g., small sample sizes, questionable observer reliability, subjects' self-selection of long- vs. short-distance commuting), we believe that on the whole, the existing literature offers converging evidence for a significant link between certain conditions of automotive and public transit and the occurrence of stress reactions among travelers. At the same time, however, the available empirical evidence provides a rather incomplete basis for understanding the specific psychological and social mechanisms that mediate the relationship between transportation and well-being and for conducting programmatic research on these issues.

A major gap in the earlier research is the absence of an integrative, theoretical, framework. This is not to say that previous work has been atheoretical, for numerous studies have been guided by detailed conceptualizations of human stress and fatigue (cf. Crawford, 1961; Forbes, 1972; Simonson *et al.*, 1968). But these conceptualizations generally reflect a medical perspective on stress. Accordingly, most experimental studies of transportation and stress have focused primarily on the physical-environmental demands of travel and correlative physiological and emotional responses, while neglecting the complex interplay of physical, social, and psychological factors that determine travelers' reactions to transportation situations.

The mediating role of individual differences (e.g., drivers' experience, medical history, and sex) has been assessed in several studies (cf.

Bellet *et at.*, 1969; Hunt & May, 1968; Mackie *et al.* (1974). However, the investigations by Singer *et al.* (1978) and Lundberg (1976) were the first to examine systematically the contribution of cognitive processes as mediators of commuters' stress reactions. Most studies have neglected to assess the interactive effects of physical, social, and psychological factors on travelers, and no systematic conceptualization of these effects has been provided by earlier work.

Consistent with a medical model of stress, earlier investigations have focused on the short-term reactions of travelers to acute environmental demands (e.g., physiological reactions resulting from excessive temperature, air pollution, or crowding), rather than on the cumulative behavioral and health consequences of chronic exposure to travel conditions. Moreover, the lack of longitudinal studies has precluded an assessment of travelers' active attempts to cope with and, in some instances, alter their exposure to unpleasant transportation situations. Lundberg's (1976) follow-up study of Stockholm commuters offers the basis for analyzing the cumulative health consequences of routine exposure to travel demands. But the focus of that research was on the short-term effects of exposure to crowded transit facilities, rather than on the possible changes in commuters' health status that may have occurred during the period between the initial and follow-up investigations.

Finally, the potential links between research on transportation and stress and long-range transportation planning have not been established. The failure to establish connections between experimental data and policy issues may be attributable, in part, to the nature of earlier theoretical and methodological approaches. Because of the focus of previous work on the short-term effects of exposure to immediate travel demands, several broader research questions that are policy-relevant have been neglected. For example, what are the social and health-related costs associated with alternative modes of commuting? And in what ways can the adverse effects of unavoidable exposure to travel constraints be reduced through transportation planning strategies (e.g., residential zoning policies, traffic management decisions)?

Considering both the contributions and shortcomings of earlier studies, we believe that an important priority for future research is the development of an ecological conceptualization of transportation and well-being. Such an analysis would (1) emphasize the multiple dimensions of transportation situations and their impact on people; (2) examine the cumulative as well as the short-term effects of transportation conditions on health and behavior; and (3) assess the ways in which people cope with prolonged exposure to travel demands. The basic elements of an ecological perspective on transportation and well-being are discussed below.

AN ECOLOGICAL ANALYSIS OF TRANSPORTATION AND WELL-BEING

At the outset of the preceding section, we noted the diverse phenomena associated with the terms *transportation* and *stress*. Our theoretical analysis of transportation and well-being, developed in this section, builds on the preceding definitions and discussion. First, we define *transportation stressors* as conditions associated with various forms of travel and travel-related environments that evoke unpleasant and/or health-threatening reactions in the individuals exposed to them. These stress reactions include emotional, physiological, and behavioral responses. In this definition, the term *transportation* refers to the conditions associated with any mode of travel (e.g., public vs. private) and to various travel purposes (e.g., work-related vs. recreational). Moreover, transportation stressors are construed broadly to include a diversity of travel conditions, such as traffic congestion, air pollution, interpersonal conflict, and the inconveniences associated with vehicle malfunctions.

Our theoretical analysis is principally concerned with the relationship between transportation stressors and personal well-being. The term *well-being* refers to multiple dimensions of mental and physical health, including personal productivity, sense of purpose, the quality of relationships with others, and levels of physiological and emotional disorder. Although the focus of our analysis is on the individual's response to transportation conditions, our ecological orientation encompasses the impact of such conditions on organizations and whole communities. Thus, we define *transportation strains* as travel-related conditions that impair organizational or community effectiveness vis-à-vis specific performance criteria (e.g., aggregate indices of health and productivity). The effects of transportation strains on organizations and communities can occur through their impact on particular individuals (e.g., commuting-related health problems of key executives within a firm) or on large numbers of people (e.g., the public health consequences of automobile emissions). From an ecological perspective, the transportation stressors experienced by individuals operate as transportation strains to the extent that they exert a detrimental impact on organizational effectiveness or community well-being.

Basic Tenets of an Ecological Approach to Transportation and Well-Being

The above definitions and distinctions reflect some of the major themes or emphases of an ecological perspective on environment, behavior, and well-being (cf. Altman, 1975; Barker, 1968; Bronfenbrenner, 1979; Kelly, 1968; Wicker, 1979). Our distinction between *transportation stressors* and *strains*, and between *personal well-being* and *organizational effectiveness*, reflects a core theme of the ecological approach, namely, the *importance of studying the links between environment and well-being at different levels of analysis*. Thus, we are concerned with the ways in which transportation conditions affect both individuals and groups of individuals. Moreover, the conditions of transportation are construed broadly to include the particular events facing individual travelers as well as communitywide circumstances that affect large sectors of the population. Certain transportation conditions are manifested simultaneously—and can be researched—at both personal and aggregate levels of analysis.

Our distinction between *specific stress reactions* and *overall well-being* reflects an additional theme of the ecological approach, namely, an *emphasis on the reciprocal influence among environments and their occupants*. Within the context of transportation, we are concerned not only with the ways in which people are affected by travel demands but also with the processes by which they actively cope with and attempt to modify these conditions. Our conceptualization of well-being, therefore, includes active modes of cognition and behavior (e.g., one's belief in and exercise of personal competence) as well as reactive modes (e.g., physiological disorders, manifestations of helplessness). Our analysis thus reflects a *transactional* rather than a linear conceptualization of the relationship between environmental conditions, on the one hand, and human behavior and well-being, on the other (cf. Lazarus & Launier, 1978; Stokols, 1978).

Our transactional view of well-being is rooted in earlier formulations of open systems theory (cf. Katz & Kahn, 1966; Maruyama, 1963; Miller, 1955; von Bertalanffy, 1950). *Open systems* have been defined as "bounded regions in space-time involving energy interchange among their parts. . . and with their environments" (Miller, 1955, p. 514). A key assumption of systems theory is that the survival and effectiveness of individuals and groups depend on their capacity to cope with environmental constraints and to accomplish their goals and activities in spite of those constraints. Thus, *personal or collective well-being essentially reflects the degree of fit (or congruence) between human goals and activities, and the environmental context in which they are pursued* (cf. French, Rodgers, & Cobb, 1974; Harrison, 1978; Michelson, 1976). Given the diversity of goals and activities that may be relevant within particular situations, the concepts of person–environment and group–environment fit are inherently multidimensional, reflecting the overall (i.e., average) level of congruence that exists between multiple goals and activities, and prevailing environmental conditions (cf. Stokols, 1979).

A fundamental feature of systems that distinguishes them from nonsystems is the interdependence of their components, and of their components and the external environment. *According to the principle of interdependence, the various ways in which people cope with environmental constraints and strive to maintain well-being are highly interrelated.* For example, an individual's reactions to the inconveniences and discomforts of a particular journey depend on several related psychological processes, including his or her personality dispositions, attitudes about the origin and destination of the trip, and resources for choosing alternative travel modes and schedules. Similarly, the relationship between transportation conditions and well-being at the community level is mediated by a host of interdependent processes, such as the spatial distribution of urban facilities and services, regional climate and topography, and the economic resources of the community.

The multiplicity of interrelated factors that affect individual and collective experiences of transportation highlights an additional emphasis of our approach, namely, *the importance of analyzing transportation and well-being from a situational or contextual perspective*. A contextual analysis requires that the relationships between specific environmental conditions and well-being be assessed within the context of particular situations and settings (cf. Bem & Funder, 1978; Magnusson, 1980). The impact of driving demands on automobile commuters, for example, may be substantially modified by their perceptions of the overall quality of their residential and employment situations. At the societal level, the implications of urban transportation conditions (e.g., widespread reliance on the automobile as the predominant commuting mode) for collective well-being must be assessed in relation to relevant aspects of the international situation at a given point in time (e.g., the availability and cost of global petroleum supplies). Furthermore, national circumstances (e.g., automobile manufacturing practices, decisions concerning the distribution of fuel, and taxation policies) and international circumstances (e.g., petroleum production and pricing) may well influence the perceptions of individuals. Reductions in the availability of fuel can lead to personal frustration and can prompt antagonistic appraisals of events in commuting situations.

From an ecological perspective, then, the relationship between transportation and well-being is construed not in terms of the isolated causal connections between independent and dependent variables but in terms of the mutually causal relationships among clusters of situationally relevant factors. An important challenge posed by our contextual approach is to identify and delineate those situations, occurring at personal and/or aggregate levels of analysis, that are of greatest theoretical and policy relevance to the study of transportation and well-being.

To summarize, we have identified five basic themes of our ecological perspective on transportation and well-being: (1) an emphasis on multiple levels of analysis; (2) the reciprocal or transactional nature of person–environment and group–environment relations; (3) the importance of person–environment and group–environment fit in determining individual and collective well-being; (4) the interdependence of adaptive and coping processes; and (5) the utility of a contextual approach in the study of environment, behavior, and well-being. These general themes provide the basis for developing more specific theoretical statements and research hypotheses. Before elaborating on the specifics of our theoretical approach, however, we first consider certain alternative directions for research that are suggested by our discussion of ecological principles. A consideration of these directions provides a backdrop for locating our specific theoretical concerns within a broader set of issues.

Conceptual Focuses of Research on Transportation and Well-Being

The ecological themes outlined above suggest several levels at which transportation and well-being can be assessed. These include the individual (i.e., single traveler), small-group (e.g., members of a car pool), organizational (e.g., private corporation), community (e.g., county transit authority), and national and international levels (e.g., the Federal or International Aviation Administration). For purposes of simplifying this discussion, we shall distinguish simply between individual and aggregate levels of analysis. If the manifestations of both *transportation conditions* and *well-being* are considered at the *individual* and *aggregate levels,* then four distinct research focuses are suggested: (1) the interplay between the specific conditions faced by an individual traveler and his or her experiences of, and efforts to cope with, those conditions; (2) the relationship between the transportation conditions faced by individuals and manifestations of organizational or community well-being; (3) the link between communitywide conditions of transportation and individual well-being; and (4) the interrelations among communitywide conditions of transportation and levels of organizational or community well-being. The intersection of these levels of analysis is depicted in Figure 1, which also presents examples of research questions corresponding to the particular focuses in the matrix.

The suggested areas of research are by no means independent. In many instances, the same (or comparable) conditions that face the individual traveler affect multitudes of others as well. Moreover, an assess-

	MANIFESTATIONS OF WELL-BEING (stress and coping processes) — INDIVIDUAL LEVEL	AGGREGATE LEVEL
TRANSPORTATION CONDITIONS (environmental and phenomenological circumstances)	Driver performance; subjective affect; physiological arousal; cognitive and behavioral functioning; enduring attitudes; health conditions; behavioral adaptation.	Organizational performance; turnover; absenteeism; industrial accidents; automobile accidents; prevalence of illness in community; social climate; utilization of public transit.
	Examples of Research Questions	
INDIVIDUAL LEVEL Proximate commuting events; perceptions of personal travel, residential, and job domains; mediating influences of personal attributes and resources; coping efforts enacted.	What are the effects of intravehicular conditions on driver performance? To what extent is perceived traffic congestion related to negative mood? How does residential satisfaction affect the response to commuting demands? Can residential relocation to minimize exposure to traffic beneficially affect health and performance?	Are worker absenteeism and turnover related to satisfaction with the commute? Do commuter frustrations affect worker productivity or rates of industrial accidents? What is the relationship between commuting satisfaction and organizational climate? What incentives are needed to encourage car-pooling and use of public transit?
AGGREGATE LEVEL Road design; physical parameters of commuting; mode of transportation; ambient conditons in commuting environment; economic constraints; governmental programs regulating travel.	What is the relationship between traffic volume and driver tension? Does long-distance commuting result in elevated blood pressure? Do heat, humidity, and smog have adverse effects on driver performance and health? What are the attitudes of commuters toward restricted lanes on freeways? Does changing one's mode of commuting to reduce driving demands have a positive health consequence?	Is the widespread reliance on the automobile a primary cause of urban sprawl? Do highway safety improvements reduce accident rates in a cost-effective manner? Is hypertension more prevalent among automobile drivers than among those who ride buses or trains? What are the public health consequences of automobile emissions? What are the transportation requirements of the elderly, the handicapped, and the poor? Is the quality of life in a metropolitan area related to its transit resources?

Figure 1. Levels of analysis in the study of transportation and well-being and research questions suggested by the intersection of these levels.

ment of personal indices of well-being is often crucial to an understanding of communitywide, aggregate health statistics. Nonetheless, the proposed classification of research focuses suggests alternative analytical perspectives and research issues that might be emphasized in the study of transportation and well-being.

While our ecological orientation subsumes a diversity of perspectives, the scope of our theoretical analysis and research program is necessarily limited (by time, resources, and expertise) to a subset of these issues. The primary focus of our analysis is on the first and third sets of issues mentioned above, namely, the relationship between conditions faced by individuals and/or large numbers of travelers and personal well-being. We also are concerned, though less directly, with the impact of such conditions on organizational effectiveness. The fourth set of issues, concerning the interrelations between communitywide transportation conditions and community well-being, is least amenable to the conceptual framework and methodological strategies described below and thus is beyond the scope of the present analysis.

Travel Impedance and Commuter Stress

Our research focuses on the behavioral and health consequences of individuals' prolonged exposure to transportation stressors. Although the studies reviewed earlier provide ample evidence that exposure to various travel demands is often associated with short-term stress reactions, they offer no direct evidence for the psychological, behavioral, and physiological residues of long-term exposure to such demands.

One category of stressors to which travelers, especially commuters, are routinely exposed is *impedance.* Sources of impedance include any circumstances (e.g., traffic congestion, traffic signals, characteristics of the vehicle) that retard or otherwise interfere with one's movement between two or more points. The degree of impedance encountered by travelers can be indexed in terms of at least two situational parameters: (1) the distance traveled between origin and destination and (2) the amount of time spent in transit between these points. Presumably, the greatest degree of impedance would result from traveling large distances slowly, whereas the least amount of impedance would arise from traveling small distances in a short amount of time.

Several areas of research, especially those relating to human aggression (cf. Berkowitz, 1965; Donnerstein & Wilson, 1976; Novaco, 1979; Rule & Nesdale, 1976) and crowding (cf. Altman, 1975; Baum & Epstein, 1978), indicate that environmental constraints can induce both physiological stress and performance deficits. Psychological analyses of stress (cf. Appley & Trumbull, 1967; Lazarus, 1966; McGrath, 1970), however, highlight the interdependence of cognitive, motivational, and physiological determinants of people's reactions to environmental demands and suggest that these reactions vary considerably across individuals.

Lazarus (1966), for example, has developed a detailed conceptualization of psychological stress emphasizing the individual's *perceived* inability to cope with *perceived* environmental demands. According to this view, a particular environmental condition (e.g., traffic congestion) is likely to prompt diverse reactions among different persons depending on their respective perceptions of the threat posed by the condition (primary appraisal) and their resources for coping with it (secondary appraisal). A variety of circumstances may affect individuals' appraisal of environmental demands and their reactions to them, including motivational factors (e.g., the desire to arrive at a meeting on time and to avoid the embarrassment of being late), cognitive factors (e.g., the unexpectedness of detours and delays along a chosen route), personality dispositions (e.g., chronic time urgency), and medical history (e.g., chronic heart disease).

The relative contribution of various environmental and personal factors to the appraisal and impact of transportation demands may vary greatly depending on the particular situation in which the traveler is involved (e.g., commuting to work vs. embarking on a vacation). In keeping with the contextual approach mentioned earlier, we assume that the potential mediators of impedance effects on well-being can be grouped in a theoretically useful manner according to the situational contexts in which they occur. An advantage of this approach is that it accounts for certain aspects of situations (e.g., their perceived quality and importance to the individual) that may moderate the relationship between situation-specific conditions and overall well-being.

Our discussion of transportation situations builds on earlier analyses of the environmental context of behavior (cf. Barker, 1968; Bronfenbrenner, 1979; Chein, 1954; Lewin, 1936; Moos, 1976; Magnusson, 1980). We first consider basic categories of behaviorally relevant situations and then delineate certain features of situations that may mediate the relationship between transportation constraints and well-being.

Categories of Situations

Our analysis incorporates two major criteria for categorizing environments: (1) the *phenomenological perspective* from which the environment is approached and (2) the *scale* or level of complexity at which it is considered. The first criterion refers to a continuum ranging from a purely physical (or objectivist) perspective to a purely perceptual (or subjectivist) one. The second criterion refers to an hierarchical ordering of environmental units reflecting their relative organizational complexity (i.e., stimuli, events, momentary situations, behavior settings, and life domains). The criteria of perspective and scale are assumed to be independent. At any level of complexity, then, the environment can be analyzed from a physical and/or perceptual perspective.

The categorization of situations in terms of phenomenological perspective is based on a distinction between the physical and the perceived environment (cf. Chein, 1954; Lewin, 1936; Magnusson, 1980; Wohlwill, 1973). Drawing upon Magnusson's distinction between actual and perceived situations, we define the *physical environment* as that portion of the geographical, architectural, biological, and sociocultural milieu that is available for sensory perception at a given point in time. The *perceived environment* is defined as the individual's perceptions and interpretations of the physical (or sociophysical) milieu. The term *perceived* refers in this discussion to both personally and collectively held impressions of an environment. Thus, the perceived environment encompasses not only the idiosyncratic impressions of a single observer but also the shared, symbolic meanings that are ascribed to the environment by a particular group (cf. Stokols, 1980; Stokols & Shumaker, 1980).

The present analysis of transportation environments adopts a "dual" perspective, emphasizing both the physical and the perceived features of situations. We are concerned, for example, not only with the physical parameters of travel impedance (e.g., the frequency and duration of one's exposure to traffic congestion) but also with the subjective severity of these conditions as perceived by the individual traveler.

The environmental contexts of human behavior can be viewed not only from different phenomenological perspectives but also at varying levels of complexity. The complexity or scale of environmental units is reflected in the diversity and intricacy of their internal elements. The least complex environmental units are stimuli and events. *Stimuli* are environmental elements (e.g., traffic signals, hornhonking) that reinforce operant behavior or function as discriminative cues for future behavior (cf. Gibson, 1960; Skinner, 1953). *Events* are chains of stimuli that appear to an observer to be causally linked (e.g., the negative consequences of being delayed by a traffic jam).

At the next highest level of complexity are *situations*, that is, clusters of stimuli and events that are functionally organized around specific goals and activities (cf. Magnusson, 1980). Magnusson distinguished between the momentary situation and the situation type. The *momentary situation* encompasses those stimuli and events that occur at a specific time (e.g., driving home from work on Pacific Coast Highway through Laguna Beach at 4:05 on January 28, 1980), within a particular *type of situation* (e.g., driving home from work along Pacific Coast Highway).

Behavior settings, as conceptualized by Barker (1968; Barker & Associates, 1978; Wicker, 1979), are regions of the physical environment that, over time, have become associated with recurring patterns of individual and collective behavior. Examples of travel-related settings are airports, bus stations, and commuter trains. In the present analysis, behavior settings are assumed to be of greater complexity than situations because of the relatively greater stability and permanence associated with the physical milieu and the social organization of the former. Moreover, several different types of situations (emphasizing interrelated, yet distinct activities) are typically associated with a particular behavior setting.

Clusters of behavior settings that are functionally linked through the shared goals of their members comprise the next most complex unit of the environment, that is, *life domains*. These contextual units pertain to different spheres of an individual's life, such as the family-residential, employment, peer-recreational, and transportation domains. Each of these domains subsumes multiple behavior settings that are functionally organized around common goals, activities, and social relationships.

Finally, the various life domains that are perceived by the individual as being relevant to personal (albeit shared) goals and activities comprise the *overall life situation* (cf. Magnusson, 1980). The life situation of a commuter, for example, might include the home, the workplace, and the commuting and recreational domains.

Psychological Properties of Environmental Domains

A basic tenet of our ecological approach is that the relationship between transportation and well-being can best be understood within the context of specific settings and environmental domains. Essentially, we assume that certain basic properties of environmental units play a crucial role in mediating the impact of context-specific stimuli and events on personal well-being. Having delineated a categorization of environmental units, it is important now to delineate concepts and measures for describing those units in ways that reflect their contribution to the enhancement or impairment of well-being.

Our effort to provide theoretically meaningful terms for describing the links between environmental contexts and well-being focuses on a crucial facet of the perceptual environment, namely, the perceived level of person–environment fit (or more simply, environmental congruence). Earlier research suggests that the overall level of congruence existing within a particular situation, setting, or domain is closely related to the well-being of participants within that context (cf. French *et al.*, 1974; Harrison, 1978; Michelson, 1976; Stokols, 1979).

As noted above, environmental congruence reflects the degree to which an individual's major goals and activities are facilitated or constrained by environmental conditions. In the present analysis, environmental congruence is construed as an intervening psychological construct that mediates the relationship between events occurring within a particular physical environment and various aspects of personal well-being, for example, a person's satisfaction with his or her commuting situation, performance level at work, and physiological stress reactions on arrival at home in the evening.

The level of environmental congruence that exists within a situation is presumed to be highly correlated with the individual's overall assessment of (and satisfaction with) the quality of that situation. Perceived situational quality depends on at least two factors: (1) *environmental controllability*, or the degree to which the individual's level of need facilitation in the situation corresponds with expected or preferred levels of outcomes; and (2) *motivational salience*, or the subjective importance of those goals and activities that are relevant within the situation. To the extent that environmental controllability is low and motivational salience is high, the likelihood of adverse emotional, behavioral, and health consequences is expected to increase (cf. Novaco, 1979; Stokols, 1979; Thibaut & Kelley, 1959).

The dimensions of environmental controllability, salience, and congruence can be assessed with respect to multiple goals and activities that are encompassed by either individual or multiple situations, settings, and domains. In the case of environmental contexts that are comprised of multiple units (e.g., the overall life situation), the overall level of congruence is indexed in terms of a composite score reflecting the average of those scores associated with the particular units (e.g., the family, employment, and transportation domains).

A key assumption in our research is that commuters' reactions to travel demands are mediated by the level of congruence (and hence the perceived quality and satisfaction) associated with those environmental contexts comprising their typical activity pattern. Chapin (1974) has defined *human activity patterns* as "the ways in which residents in metropolitan communities go about their daily affairs" (p. 23). These patterns collectively comprise the *urban activity system*, that is, "the patterned ways in which individuals, households, institutions, and firms pursue their day-in and day-out affairs in a metropolitan community and interact with one another in time and space" (p.23). In relation to the environmental categories introduced earlier, it should be noted that activity patterns are less encompassing than the individual's overall life situation. That is, activity patterns subsume those places and settings in which people are regularly involved on a day-to-day basis. The life situation, on the other hand, could include life domains (e.g., relationships with family or friends in a distant community) that are less closely associated with the daily activities of the individual. As a basis for simplifying our analysis of commuting and well-being, we shall focus on the major components of the commuter's activity pattern (i.e., the commuting, residential, and employment domains) rather than examining all facets of the commuter's life situation. Moreover, while Chapin's concept of the urban activity system offers a basis for describing community-level conditions and their implications for aggregate well-being, these issues are beyond the scope of our more limited analysis of the environmental contexts of individual behavior and well-being.

General Propositions Derived from Our Theoretical Analysis

The preceding conceptualization of travel impedance and of the environmental contexts in which it occurs suggests at least three general propositions for empirical investigation. These propositions reflect several of the ecological principles mentioned earlier.

First, we propose that the effects of routine exposure to travel impedance on the well-being of commuters is mediated by several interdependent factors, including the duration of the commute, the perceived severity of traffic congestion, and personal dispositions toward impatience and time urgency. This hypothesis reflects the ecological emphasis on the interdependence of adaptive processes.

Second, we propose that prolonged exposure to travel impedance not only evokes stress reactions but also prompts active efforts among travelers to improve their commuting situations (e.g., by moving closer to work, by changing their travel schedule or route). This hypothesis reflects the ecological emphasis on the transactional nature of person-environment relations.

Third, we propose that the relationship between travel impedance and personal well-being is mediated by the perceived quality of those domains comprising the commuter's typical activity pattern. This prediction reflects the ecological theme of assessing personal well-being in terms of the degree of fit between an individual's goals and activities and the environmental conditions that exist within specific contexts. An important implication of this hypothesis is that the perceived costs and constraints associated with the commuting situation may be compensated for by certain desirable features of one's residential and employment situations (cf. Campbell, 1979). This process of compensatory coping may be manifested both in the commuter's subjective appraisal of the travel situation and in enhanced levels of emotional and physical well-being.

So that we might clarify the series of conceptualizations that we have thus far presented, a summary of the key ideas is contained in Figure 2. Here we illustrate the sequential linkage of our research propositions to the array of conceptual foci in transportation research, which in turn follows from the set of ecological tenets guiding our analysis.

To address the above propositions within the same investigation, we employed a longitudinal field experiment focusing, initially, on environmental and personal determinants of commuters' stress reactions and subsequently, on commuters' active efforts to cope with travel constraints. We should note that the experiment to be described was initially designed to test specific predictions derived from a psychological model of commuting stress, rather than the more general propositions suggested by the ecological framework presented above. Our development of a broader ecological framework, in fact, was prompted by certain empirical findings from the first phase of our experiment. Therefore, several of the measures incorporated in our study do not provide as specific an assessment of certain aspects of our ecological framework as, in retrospect, we would have preferred. Our assessment of person-environment fit, for example, relies on global measures of residential, commuting, and employment satisfaction, rather than on specific measures of the perceived controllability and salience of those domains. For the most part, however, we believe that the experimental design and categories of measures employed in our study are sufficiently close to the concepts developed earlier to provide the basis for a preliminary assessment of our ecological analysis.

A FIELD-EXPERIMENTAL INVESTIGATION OF TRAVEL IMPEDANCE AND COMMUTER WELL-BEING

This section provides a general overview of our research methodology and findings. A more detailed description of the research design and methodology can be found in our earlier articles (Novaco, Stokols,

BASIC THEMES OF AN ECOLOGICAL APPROACH

1. Study of environment–behavior relationships at different levels of analysis.
2. Emphasis on reciprocal influences among environments and their occupants.
3. Attention to congruence between goals and the environmental arena of their pursuit.
4. Recognition of interdependence among components of the coping process.
5. Recognition of the importance of a contextual perspective for understanding behavior and well-being.

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CONCEPTUAL FOCUSES IN RESEARCH IN TRANSPORTATION

A. Transportation conditions faced by individuals and their experience of and efforts to cope with those conditions.
B. Transportation conditions faced by individuals and the manifestations of organizational and community well-being.
C. Communitywide conditions of transportation and individual well-being.
D. Communitywide conditions of transportation and organizational and community well-being.

→

LONGITUDINAL RESEARCH ON IMPEDANCE STRESS AND ADAPTATION

Focuses emphasized:
A and C

Propositions examined:

1. Effects of travel impedance are determined by interdependent factors in the commuting context, such as travel parameters, perceptions of congestion, personal dispositions, and vehicular conditions.
2. Prolonged exposure to travel impedance evokes stress reactions and prompts coping efforts intended to improve the commuting situation.
3. The relationship between travel impedance and personal well-being is mediated by the perceived quality of life domains in the commuter's activity pattern.

Figure 2. Basic tenets, general research focuses, and specific study propositions.

Campbell, & Stokols, 1979; Stokols, Novaco, Stokols, & Campbell, 1978).

Method

Subjects

The present study utilized a longitudinal, field-experimental design in which urban commuters, traveling varying distances between home and work, were tested during the summer of 1976 (Phase 1) and approximately 18 months later, during the winter of 1978 (Phase 2). The participants were 100 paid volunteers recruited from two large industrial firms in Irvine, California. The employees of these companies were contacted by letter and asked to indicate their willingness to participate in a study of "Commuting Patterns, Health, and Performance." From among those employees who responded affirmatively to our request for volunteers, 100 individuals were selected on the basis of the following criteria: (1) the average distance and duration of their daily commute to and from work; (2) their time of arrival at work; and (3) the number of months during which they had traveled their current commuting route.

The Phase 1 sample consisted of 61 males and 39 females, all of whom were on the day shift and had traveled the same route for more than eight months. The Phase 2 sample consisted of those individuals who had participated during Phase 1 and were still employed by the same companies 18 months later. Of the original 100 participants, 18 individuals had quit their jobs between the summer of 1976 and the winter of 1978. An attempt was made to contact these individuals, but most had left the Irvine area and could not be reached. The remaining 82 individuals, including 49 males and 33 females, agreed to participate in the second phase of the study when recontacted by phone.

Selection of Subjects for Experimental Groups

On the basis of information obtained from an initial Phase 1 screening questionnaire, the boundary criteria for three major impedance groups were derived. *Low-impedance* subjects were those falling within the bottom 25% of the distributions of commuting distance and time. This group was comprised of 27 persons who traveled less than 7.5 miles between home and workplace and spent less than 12.5 minutes on the road in either direction. *Medium-impedance* subjects fell into the middle 30% on the time and distance distributions and consisted of 22 persons traveling between 10 and 14 miles and spending approximately 17–20 minutes on the road each way. *High-impedance* subjects fell into the top 25% of the distance and time distributions and consisted of 36 persons traveling between 18 and 50 miles and spending from 30 to 75 minutes in the commute.

The above impedance groups included only those persons having correspondent positions along the distance and time distributions (i.e., low/low, medium/medium, high/high). A subset of the experimental sample displayed noncorrespondent rankings with regard to the time and distance distributions. These persons were excluded from statistical analyses involving an assessment of the three-level impedance factor, but they were included in all other analyses.

By Phase 2, the number of participants within the low-, medium-, and high-impedance conditions were 18, 19, and 26, respectively. These reduced cell frequencies are attributable to the attrition of 18 participants by Phase 2 and to the fact that 11 of the remaining 82 subjects had altered their impedance ranking through residential relocation between phases 1 and 2. All statistical analyses of the effects of impedance on repeated measures (i.e., those administered at both Phases 1 and 2) are based on the constant-impedance sample ($n = 63$ across low-, medium-, and high-impedance cells). Several of the other analyses performed at Phase 2, however, are based on the data of all 82 individuals who participated during both phases of the study.

Just prior to Phase 1, the subjects were informed of their selection by mail and were requested to complete a series of background and personality questionnaires. Included in this set of measures was the Jenkins Activity Survey for Health Prediction (JAS), a measure of the coronary-prone behavior pattern (Jenkins, Zyzanski, & Rosenman, 1971; Zyzanski & Jenkins, 1970). Within each of the three main impedance groups, the subjects were classified as either Type A or Type B on the basis of their JAS score (see Stokols *et al.*, 1978, for a description of the scoring procedure used to determine A-B classification).

In addition to the JAS, all participants completed Rotter's (1966) Internal-External Locus of Control Scale (I-E) and Novaco's (1975) Anger Inventory (AI). The incorporation of the JAS, I-E, and AI scales in the present study was based on the assumption that coronary-prone behavior, chronic internality of control, and anger might mediate commuters' reactions to travel impedance. In this chapter, we summarize certain findings relating to the JAS and the I-E. A detailed discussion of the interactive effects of I-E and impedance, and Type A behavior and impedance, can be found in Novaco *et al.* (1979) and in Stokols *et al.* (1978), respectively.

Testing Procedure

In Phase 1, subjects were contacted by phone to schedule their participation times. Each subject participated in the study for one week. During this time, they completed five daily commuting logs pertaining to the actual distances and times traveled each day and to subjective impressions of the journey (e.g., perceived congestion, air quality, and temperature inside the vehicle). These logs were completed on arrival at work and at home for the morning and afternoon commutes.

Upon arrival at work on Monday, Wednesday, and Friday, the employees drove to a testing station located in the parking lot of their company. There, each person's systolic and diastolic blood pressure were recorded using a Physiometrics SR-2 automatic blood pressure recorder. Heart rate was also measured by means of a cardiotachometer attached to the blood pressure recorder.

On Tuesday and Thursday of the testing week, the participants reported to a company conference room approximately 1½ hours after arriving at work. Here, measures of blood pressure, heart rate, and mood were again obtained. Subsequently, one or two brief tasks were administered to assess the cumulative effects of impedance on psychomotor performance and tolerance for frustration.

During the Tuesday session, the subjects performed the "perceptual reasoning" test developed by Feather (1961). The test consists of four puzzles, two of which are insoluble (Puzzles 1 and 3) and two of which are soluble (Puzzles 2 and 4). The subjects were asked to trace the lines of a diagram without lifting the pen or retracing a line. This task has been employed by Glass and Singer (1972) as a measure of frustration tolerance and has been found to be sensitive to the aftereffects of environmental stressors.

During the Thursday session, the subjects performed the digit symbol task from the Wechsler Adult Intelligence Scale (Wechsler, 1958). The task is a measure of psychomotor speed and concentration in which persons are required to copy the symbols associated with a line of digits into rows of boxes over a 90-second period. Immediately after performing this task, the subjects were administered a memory test in which they were given 30 seconds to recall the symbols associated with the nine digits of the Wechsler task.

On completion of the testing week, all subjects were provided with a summary of their daily blood pressure and heart rate readings, as well as a detailed explanation of the research procedures. All individuals were paid $10 for their participation during Phase 1.

Eighteen months after the initial testing session, all subjects were sent a letter requesting their participation in the second phase of the study. Those individuals still employed by the same companies agreed to participate and were sent a follow-up questionnaire concerning personal health status and satisfaction with employment, residential quality, and the commute between home and work. Enclosed with the questionnaire was an invitation to attend a presentation by the authors of the findings from the first phase of the study. This presentation was held in a conference room at each of the participating firms. The Jenkins Activity Survey (JAS) was readministered to all participants just prior to the authors' presentation. The participants were paid $5 for completing the Phase 2 questionnaires.

Major Categories of Dependent Measures

Several of the measures utilized in this study were administered at both Phases 1 and 2. The remainder were administered at Phase 1 or at Phase 2 only.

The repeated measures consisted of three basic categories: (1) general mood on arrival at home from work; (2) self-reported satisfaction with various life domains, including residential, employment, and community situations; and (3) attitudes regarding environmental problems and transportation management strategies. Items relating to each of these categories were contained in the background and follow-up questionnaires. In addition, a number of miscellaneous questions concerning personal and demographic issues (e.g., length of time at current residence and job; socioeconomic status; type of car owned; history of traffic accidents; alcohol consumption; exercise regimen) were administered at both phases of the study.

The mood index consisted of six bipolar scales (e.g., tense-relaxed, tired-energetic) pertaining to the individual's typical emotional state on arrival at home from work. A series of semantic differential scales also were used to assess commuters' satisfaction with their commute, residence, and job. Ratings of the commuting situation, for example, included two 7-point scales regarding the extent to which the subjects were inconvenienced by traffic congestion and satisfied with their commute. Residential satisfaction was indexed by three 7-point scales pertaining to residential crowding, desire to relocate, and overall satisfaction with current residence. In addition, the subjects were questioned about the degree of choice they had exercised in deciding where to live and the extent to which they wanted to move from their current residence because of traffic-related problems. Job satisfaction was measured by five Likert items concerning different dimensions of employment (e.g., feelings of accomplishment derived from the job; adequacy of current salary) and with two additional sets of semantic differential scales pertaining to the quality of social and physical conditions at work. Finally, the subjects' attitudes about the severity of urban environmental problems (i.e., traffic congestion, air pollution) and their agreement with potential transportation management strategies (e.g., development of company-sponsored "van pool" programs; use of traffic-metering devices on major thoroughfares) were assessed with eight 7-point scales.

Physiology and task performance were measured during Phase 1 only. Systolic and diastolic blood pressure and heart rate were measured on each day of the testing period as described earlier. The principal measures of task performance were (1) the number of attempts made by each subject on Feather's (1961) insoluble puzzles; (2) the number of boxes correctly completed on the digit symbol task; and (3) the number of symbols recalled in the digit-symbol memory task.

Additional measures administered at Phase 1 only included a nine-item mood scale completed by each commuter on arrival at work in the morning, and the five daily travel logs completed on arrival at work and at home for the morning and afternoon commutes. These logs assessed commuters' impressions of traffic conditions and provided a record of daily commuting distances and times.

Several sets of questionnaire items were administered only at Phase 2. These included an index of the frequency and severity of health problems occurring between Phases 1 and 2 (e.g., number of occasions on which various illnesses occurred; number of days hospitalized) and a measure of the frequency ("not at all"-"often") with which medication was taken in relation to chronic health problems. Also administered at Phase 2 were self-reports of activities undertaken to alter and to cope more effectively with commuting and residential situations (e.g., purchase of a new car, alteration of commuting schedule or travel mode, residential relocation, increase in the weekly rate of physical exercise between Phases 1 and 2). A related set of items assessed the availability of special features (e.g., tape deck, air conditioning) in the vehicle that served to enhance the quality of the journey between home and work and the individual's reasons for purchasing his or her current commuting vehicle. Finally, several semantic-differential scales were incorporated into the Phase 2 questionnaire to provide validity checks on our conceptualization and measurement of impedance. For instance, the subjects were asked to estimate the frequency ("very rarely"-"very often") at which they found it necessary to apply their brakes while driving between home and work and to reduce their travel speed because of constraints such as traffic signals, traffic jams, and accidents. Also, the subjects were asked to indicate the number of points in their commute at which they changed from freeways to surface streets and to estimate the percentage of their trip between home and work spent on freeways or on other major, limited-access highways.

Statistical Analyses of Phase 1 and Phase 2 Data

Those measures administered during both phases of the study were analyzed in terms of a repeated-measures analysis of variance (ANOVA) design, incorporating the factors of impedance (low, medium, and high), time (Phase 1 and Phase 2), and dimensions that were expected to mediate the effects of impedance on commuters (e.g., coronary-prone behavior, internal-external control). All repeated-measures analyses were based on the constant-impedance sample ($n=63$). In those analyses incorporating an additional factor (e.g., median split on the JAS scores), the data from subjects whose position on that factor shifted between Phases 1 and 2 (e.g., from Type A at Phase 1 to Type B at Phase 2) were excluded.

The measures administered only at Phase 1 or at Phase 2 were analyzed separately in terms of one-way (impedance) or two-way (impedance × personality factor) ANOVAs. Chi-square analyses were performed on dichotomous variables as described below.

Results

The results summarized here represent only a small portion of the findings from our investigation. Our strategy in this chapter is to present a sampling of the findings that are pertinent to the three general propositions mentioned earlier. For a more detailed discussion of the Phase 1 analyses and findings, see Stokols *et al.* (1978) and Novaco *et al.* (1979)

Proposition 1: The effects of routine exposure to travel impedance on commuters' well-being is mediated through an interplay of personal and environmental factors. This hypothesis is based on at least two specific assumptions: (1) that sources of impedance operate as environmental demands that evoke adverse reactions in travelers and (2) that the impact of impedance on specific individuals is determined by both personal and situational circumstances. To test the adequacy of these assumptions, it is first necessary to assess the construct validity of the impedance factor, defined in this study by the dimensions of commuting distance and duration; and, second, to demonstrate that travel impedance is reliably associated with stress reactions.

Evidence for the construct validity of the impedance factor is presented in Table 1. The pattern of means reflected in participants' ratings of their commute indicate that at both Phases 1 and 2, higher levels of impedance were associated with greater perception of traffic congestion as an inconvenience [$F(2,54) = 5.22$, $p<.009$] and lower satisfaction with the commute [$F(2,55) = 9.86$, $p<.001$]. Also, across all impedance groups, the perception of congestion increased and commuting satisfaction decreased between Phases 1 and 2 [$F(1,54) = 7.32$, $p<.009$; and $F(1,55) = 8.52$, $p<.005$, respectively]. And on Phase 2 ratings of the commute, individuals in the high-impedance groups reported that they encountered conditions of heavy traffic and traffic jams more often than did low-impedance commuters [$F(2,57) = 14.98$, $p<.008$; $F(2,51) = 20.07$, $p<.006$, respectively]. That the above findings are attributable to travel demands rather than to subject self-selection biases across experimental groups is suggested by the lack of impedance main effects on the demographic dimensions of age, socioeconomic status (SES), education, and sex.

The focus of our analysis is on the interactive effects of travel impedance and personal factors on well-being. Before considering these effects, however, it is important to note that physical parameters of commuting appear to be independently related to heightened physiological arousal and health problems. Commuting distance, for example, was found to be significantly correlated with systolic and diastolic blood pressure at Phase 1 [$r(62) = .26$, $p<.01$, $r(62) = .25$, $p<.02$]. Also, the number of days hospitalized for various illnesses between Phases 1 and 2 was significantly related to the total number of interchanges between surface streets and expressways during the commute to work [$r(67) =$

TABLE 1
MEAN RATINGS OF THE COMMUTE DURING PHASES 1 AND 2[a]

Impedence condition	n	Satisfaction with commute: Phase 1 M	Phase 1 SD	Phase 2 M	Phase 2 SD	Traffic congestion as an inconvenience: Phase 1 M	Phase 1 SD	Phase 2 M	Phase 2 SD
Low	18	5.94	1.20	5.64	1.22	3.18	1.94	4.35	2.09
Medium	19	5.56	1.26	4.38	1.63	4.13	2.00	4.60	2.16
High	26	4.48	1.26	4.12	1.62	4.84	1.57	5.64	1.58

[a] Both items are 7-point semantic differential scales. Larger means indicate higher scores on the attribute listed.

.55, $p<.001$]. This relationship between stages of the journey and health status parallels the findings of Taylor and Pocock (1972), discussed earlier.

The dimension of coronary-prone behavior was one of the factors incorporated in this study to assess the interactive effects of impedance and personal characteristics on well-being. Previous research indicates that Type A's typically strive harder than Type B's to avoid loss of control over their environment, but that A's are more adversely affected by highly uncontrollable situations than are B's (cf. Krantz, Glass, & Snyder, 1974). Moreover, time-urgent A's become more impatient and irritated when they are delayed by co-workers on joint decision-making tasks (Glass, 1977). Thus, we expected that among high- and medium-impedance subjects, greater stress (i.e., negative mood, performance deficits, and elevated physiological arousal) would be manifested by A's than by B's.

As indicated in Table 2, significant AB × impedance interaction effects were obtained on Phase 1 measures of systolic blood pressure [$F(2,55) = 3.34$, $p<.04$] and performance on a tolerance-for-frustration task [$F(2,56) = 5.02$, $p<.01$].[6] But contrary to our initial expectations, the pattern of means on these variables suggests that among high-impedance commuters, Type B's experienced greater stress than Type A's; and among medium-impedance commuters, A's experienced greater stress than B's.

The relatively greater job involvement and residential choice of A's vis-à-vis B's have been suggested as possible contributors to the elevated stress levels of Type B-high-impedance commuters (cf. Stokols *et al.*, 1978). Moreover, the possible lack of fit between the impatient style of Type A's and their greater exposure to low-speed, surface street (vs. higher-speed expressway) travel under medium- versus high-impedance conditions may have contributed to the heightened stress reactions among medium-impedance A's. Our consideration of these issues in light of the findings from Phase 1 prompted us to develop a broader conceptual framework in which the interdependencies among individuals' residential, employment, and commuting situations were explicitly considered. The role of residential choice in mediating workers' reactions to their commute is discussed more fully in the ensuing discussion of our third proposition.

Proposition 2: Prolonged exposure to the demands of travel impedance prompts active efforts among commuters to improve their commuting situations. This hypothesis is based on our transactional view of person–environ-

[6]High-impedance subjects reported significantly greater feelings of annoyance on arrival at work than did low-impedance subjects, but the predicted AB × impedance interaction effects on indices of mood and on digit-symbol task performance were not significant.

TABLE 2
PHASE 1 BLOOD PRESSURE AND TASK PERFORMANCE LEVELS[a]

Condition	n	Systolic blood pressure M	Systolic blood pressure SD	Diastolic blood pressure M	Diastolic blood pressure SD	Attempts on puzzles 1 & 3 (insoluble) M	Attempts on puzzles 1 & 3 (insoluble) SD
Low impedance							
Type A	11	122.64	12.22	74.75	3.50	14.45	7.29
		(11.06)	(.54)	(8.36)	(.20)	(2.51)	(.65)
Type B	10	124.20	14.82	76.50	9.92	11.50	3.92
		(11.13)	(.67)	(8.73)	(.57)	(2.39)	(.33)
Medium impedance							
Type A	6	135.83	7.47	80.50	6.72	15.33	9.73
		(11.65)	(.32)	(8.97)	(.37)	(2.47)	(.88)
Type B	12	126.50	16.47	75.58	8.71	16.17	6.51
		(11.23)	(.73)	(8.68)	(.50)	(2.71)	(.38)
High impedance							
Type A	15	125.93	8.00	76.47	7.10	18.27	6.17
		(11.22)	(.36)	(8.74)	(.41)	(2.85)	(.34)
Type B	10	138.90	11.30	82.00	8.30	10.00	6.82
		(11.78)	(.48)	(9.05)	(.46)	(2.06)	(.77)

[a]Numbers in parentheses are transformed means and standard deviations. Transformations of puzzle data are logarithmic. Transformations of blood pressure are based on the square root of the original means.

ment relationships. The evidence for or against a transactional view of commuting and well-being can be assessed with relation to at least three specific questions: (1) What percentages of workers take active steps to alter or otherwise cope with their commuting situations? (2) What personal and situational attributes are predictive of coping efforts? (3) Are efforts to cope with travel constraints effective; that is, do such efforts enhance personal well-being?

To assess the prevalence of coping efforts among commuters, we asked participants at Phase 2 whether or not they had altered their travel schedule to avoid traffic congestion; altered their mode of commuting; purchased a new car; or changed their residence between Phases 1 and 2. The percentages of individuals who had engaged in these activities were 35%, 25%, 37%, and 32%, respectively (n=82). These figures suggest that active efforts to cope with transportation constraints are not uncommon among commuters.[7]

[7]An important issue that is not addressed by our research concerns the timing of coping efforts. Because we are interested in the health and behavioral effects of prolonged exposure to commuting constraints, we chose to study commuters who had been traveling the

As for the environmental and personal antecedents of coping, chi-square analyses revealed that the percentages of individuals engaging in coping activities were not significantly different across impedance groups. The findings presented in Table 3, however, suggest that individuals scoring high on a summary index of coping behavior between Phases 1 and 2 were more likely to have been dissatisfied with their commuting situation [$t(67) = 2.67$, $p<.009$] and bothered by traffic congestion at Phase 1 [perceived congestion during evening commute, $t(67) = 2.90$, $p<.005$; congestion as an inconvenience, $t(67) = 2.89$, $p<.001$]. At the same time, high scorers on the coping index were less time-urgent [$t(67) = 3.43$, $p<.001$] and exhibited lower diastolic blood pressure [$t(67) = 2.12$, $p<.038$] than low scorers. Moreover, females displayed a greater tendency to cope with commuting demands than did males under high-impedance conditions (Fishers' Exact Test = .08), and Type B individuals were more likely to cope than were Type As [$\chi^2(1) = 5.21$, $p<.02$], across all impedance conditions.

The summary index of coping behavior was derived by assigning each individual a score of 0 or 1 on three of the dimensions mentioned above, that is, alteration of commuting schedule (e.g., 0 = same schedule, 1 = altered schedule), change of travel mode,[8] and purchase of a new commuting vehicle. The dimension of residential relocation was omitted from the index since analyses included only constant-impedance subjects. In place of the relocation dimension, a fourth aspect of coping was added to the summary index, namely, whether or not the individual had increased or decreased his/her average number of exercise hours per week between Phases 1 and 2 (where 0 = decreased hours or stayed the same, and 1 = increased hours of exercise). Each person's scores on the four coping dimensions were summed and a median split was performed on the subjects' total coping scores to form the low-coping and high-coping groups.

Summary scores similarly were computed to assess overall levels of residential, commuting, and job satisfaction at Phases 1 and 2 (these

same route for at least eight months prior to our first testing session. This selection strategy precluded a comparison of coping efforts and health outcomes among long-term commuters versus those who had been on the route for relatively shorter (or longer) amounts of time. An important direction for future research is to examine the processes of long-term as opposed to short-term adaptation and coping with commuting constraints.

[8]The index of travel mode alteration was the total number of changes (e.g., joining a company van pool, switching from private automobile to public or corporate commuting vehicle) made by the individual. For purposes of computing the summary index of multiple coping activities, each individual's score (i.e., 0 or 1) on the mode change item was based on a median split of the mode-change total scores.

TABLE 3
DIFFERENCES BETWEEN LOW AND HIGH SCORERS ON A SUMMARY INDEX OF COPING BEHAVIOR[a]

Variable	Individuals scoring low on coping index ($n = 37$)		Individuals scoring high on coping index ($n = 32$)			
	M	*SD*	*M*	*SD*	*t* value	alpha
Commuting satisfaction, Phase 1	5.62	1.16	4.77	1.45	2.67	<.009
Perceived congestion during evening commute, Phase 1	4.31	1.74	5.46	1.42	−2.90	<.005
Perception of traffic congestion as an inconvenience, Phase 1	3.47	1.61	4.70	1.84	−2.89	<.005
Chronic time urgency (*S* factor score on JAS), Phase 1	1.24	9.33	−5.34	6.42	3.42	<.001
Diastolic blood pressure, Phase 1	77.19	7.57	73.10	8.17	2.12	<.038
Difference score (Phase 2-Phase 1 on a summary index of overall satisfaction with commuting, residential, and employment domains	−.15	2.18	1.08	2.15	−2.12	<.038

[a]Larger means indicate higher scores on the attribute listed.

scores were based on five, two, and four separate scales within the three satisfaction domains, respectively).[9] Frequency distributions and tertile splits were computed for each item, and each subject was assigned a score of 1, 2, or 3 (corresponding to low, medium, or high tertiles) on each scale. The sum of the individual item scores within each domain yielded a summary index of residential, commuting, and job satisfaction. Moreover, the sum of these domain scores yielded an index of overall satisfaction across all three domains.

By comparing each individual's levels of overall satisfaction at Phases 1 and 2, we derived a satisfaction change score based on the dif-

[9]Residential satisfaction summary scores were based on the following repeated measures: (1) the desire to change residence: (2) the reporting of commuting inconvenience as a reason for wanting to move: (3) perceived crowding in the home: (4) residential choice: and (5) residential satisfaction. The commuting satisfaction index was based on the two items listed in Table 1: (1) perception of traffic congestion as a frequent inconvenience and (2) satisfaction with the commuting process. The job satisfaction index incorporated the individual's total scores on separate sets of items pertaining to (1) ratings of the physical environment at work; (2) ratings of the social environment at work; (3) job satisfaction in general; and (4) the individual's job involvement (J factor) score on the JAS.

ference between Phase 2–Phase 1 levels of overall satisfaction. As can be seen in Table 3, high scorers on the coping index manifested higher levels of overall satisfaction by Phase 2, whereas low scorers exhibited lower levels of satisfaction at Phase 2 than at Phase 1 [$t(67) = 2.12$, $p < .038$].

Further evidence that efforts to cope with commuting constraints are effective is presented in Table 4. These data indicate that among high-impedance commuters ($n = 82$, including those who subsequently changed impedance level), 62% of the high-satisfaction individuals at Phase 2 had made efforts to alter their commuting mode (e.g., by joining or quitting car pools and van pools, and/or by substituting public transit, bicycling, or walking for prior automobile commuting) between Phases 1 and 2, while only 20% of the low-satisfaction subjects had implemented changes in their commuting mode (Fisher's Exact Test = .031).

Proposition 3: The relationship between routine exposure to travel impedance and personal well-being is mediated by the perceived quality of those domains comprising the commuter's typical activity pattern. This hypothesis reflects our emphasis on the contextual (or domain-specific) mediators of transportation and well-being. Two basic sets of analyses were employed to test the hypothesis: (1) a series of regression analyses in which Phase 1 indexes of impedance (e.g., commuting distance, self-reported frequency of braking during the commute), personality, residential choice, and job involvement were utilized to predict overall satisfaction at Phase 2, both within and across different activity domains; and (2) a series of satisfaction × impedance, repeated-measures ANOVAs performed on Phase 2 indexes of well-being, and including only those subjects whose rankings on the satisfaction and impedance dimensions had remained constant between Phases 1 and 2. In this chapter, we discuss only a subset of the regression analyses.

TABLE 4
DISTRIBUTION OF HIGH-IMPEDANCE COMMUTERS BY OVERALL SATISFACTION AT PHASE 2 AND BY ALTERATION OF COMMUTING MODE BETWEEN PHASES 1 AND 2[a]

	Alteration of commuting mode	
Overall satisfaction at Phase 2	Low scorers on index of commuting mode alteration ("low coping")	High scorers on index of commuting mode alteration ("high coping")
Low satisfaction	12	3
High satisfaction	5	8

[a] Fisher's Exact Test = .031.

In all regression equations, the dimensions of age and SES were entered at Step 1 as covariates for those criteria with which they were significantly correlated. At the next step, either commuting distance or an index of brake application during the commute was entered. The dimensions of residential choice, job involvement, and I-E were entered next in a stepwise procedure to determine whether or not these variables accounted for a significant proportion of the variance once the covariates and impedance dimension had been entered into the regression equation. All analyses were based on the constant-impedance sample.

The impedance index of distance was found to be significantly associated with overall commuting satisfaction at Phase 2, while the braking index was significantly related to the Phase 2 summary scores of overall satisfaction (across domains), commuting satisfaction, and residential satisfaction. The prediction of Phase 2 commuting satisfaction by commuting distance and Phase 1 measures of I-E, residential choice, and job involvement is summarized in Table 5. The data indicate that perceived residential choice at Phase 1 (one of the components of the residential-satisfaction summary index) did contribute significantly to the prediction of emotional well-being (i.e., overall commuting satisfaction at Phase 2), once the dimensions of SES, travel distance, and I-E had been entered into the equation.

The above findings provide partial support for a contextual analysis of transportation and well-being and are consistent with our earlier interpretation of the AB × impedance effects on physiology and performance. Specifically, they suggest that the effects of impedance on commuters depend not only on personality attributes but also on the degree of person–environment fit within various life domains.

SUMMARY AND IMPLICATIONS

We have delineated a framework for the ecological analysis of transportation and well-being and have presented a partial overview of findings from our longitudinal research in support of our central propositions. Evaluating the adequacy of our ecological perspective will surely require a more thorough analysis than we offer here. However, the reported findings are a preliminary corroboration of the theoretical scheme.

The data from our field-experimental study support our major assumptions concerning travel impedance and the mediational role of psychological (cognitive–personality) factors. The distance and time parameters of travel, indeed, reflect or index the behavioral constraint

TABLE 5

PREDICTION OF PHASE 2 COMMUTING SATISFACTION BY PHASE 1 INDEXES OF TRAVEL DISTANCE, PERSONAL CONTROL EXPECTANCIES, RESIDENTIAL CHOICE, AND JOB INVOLVEMENT[a]

Predictor variable	Step	Multiple r	Cumulative r^2	Simple r	Beta	Reliability of regression
Socioeconomic status (covariate)	1	.418	.161	.418	.418	$F(1,59) = 12.49$, $p < .001$
Distance	2	.580	.313	−.369	−.404	$F(2,58) = 14.17$, $p < .001$
External control expectancies (on I-E scale)	3	.607	.335	.220	.182	$F(3,57) = 2.87$, $p < .050$
Residential choice	4	.635	.361	.139	.198	$F(4,56) = 3.26$, $p < .025$
Job involvement (factor J on JAS)	5	.642	.358	.018	.111	n.s.

[a] Multivariate $F(4,56) = 9.46$, $p < .001$, at Step 4. Each of the univariate F's reflects the significance of the predictor variable at the step at which it was entered into the equation.

properties of commuting as a phenomenological reality. The empirical link between our operationalized conditions of impedance and the commuters' subjective evaluations of travel conditions in terms of congestion, inconvenience, dissatisfaction, and impediments to movement demonstrate that our research addresses both the physical and the perceived environment. Second, in consonance with psychological perspectives on stress, cognitive and personality factors were found to mediate the impact of routine exposure to adverse environmental conditions. To be sure, the precise nature of this mediation is multifaceted and is beyond determination by tests of statistical interaction. The complex interplay of personal and environmental factors necessitates the study of coping adaptation over time.

Our conceptualization of travel impedance, its environmental contexts, and the adaptation efforts of commuters led to the formulation of several hypotheses, each of which was supported by our findings. In general, the data suggest that (1) conditions of travel impedance are associated with stress reactions (e.g., physiological arousal, negative mood, and performance deficits), but these reactions are mediated by person variables and their reciprocal influence on environmental contexts; (2) the subjective experience of commuting as negatively toned leads to active efforts to alter or otherwise cope with commuting demands; (3) efforts to cope with commuting demands enhance perceptions of personal well-being, as reflected in levels of satisfaction across life domains; and (4) life domains are interconnected, as dimensions of satisfaction within the residential domain (e.g., residential choice) prospectively influence the effects of commuting demands on level of satisfaction within the transportation domain.

Some Qualifications of Our Findings

The specific results of our research must be regarded as preliminary in view of several methodological considerations. First, we have studied a small sample of urban commuters whose characteristics may or may not be representative of commuters in other communities and employment situations. The generalizability of our findings remains to be assessed in future studies employing larger samples drawn from different geographical locations. Existing data from national surveys of commuting conditions, employment demands, and well-being (e.g., Quinn & Staines, 1979) could provide the basis for such comparisons.

Second, like earlier field studies of commuting and stress (cf. Singer *et al.*, 1978; Lundberg, 1976), our quasi-experimental investigation poses the problem of nonrandom distribution of subjects across experimental conditions. In an effort to deal with this problem, we have attempted to control for the potentially confounding effects of demographic factors through statistical procedures. Moreover, the use of a longitudinal research design in which the effects of the experimental factors are assessed at different points in time offers a stronger basis for attributing the findings to experimental conditions than does a cross-sectional design.

One potentially confounding factor that has not been controlled in our research is the increased exposure to air pollution associated with long-distance, rush-hour commuting. Earlier studies (e.g., Aronow *et al.*, 1972; Chaney, 1978) indicate that exposure to elevated levels of carbon monoxide while traveling is associated with physiological and behavioral impairments. Although we have not accounted for these effects in our research, certain of our findings (e.g., the impedance main effects on perceived congestion) suggest that the behavioral constraints associated with travel impedance exert significant effects on well-being, above and beyond those attributable to air pollution alone. Moreover, the interaction effect among impedance and personal factors, such as Type A/Type B, argues against the explanation of stress effects as primarily due to air pollution, since there were no differences between A's and B's in the distance of the commute.

The reported study suggests several issues for future research that are both theoretically and practically important. First, while focusing on the health and behavioral consequences of automobile commuting, we have not yet examined the relative health costs associated with alternative modes of travel (e.g., car pools, van pools, and public transit vs. solo automobile commuting). Second, we have focused primarily on the relationship between commuting conditions and personal well-being while neglecting to assess the impact of transportation conditions on organizational effectiveness and community well-being. Our findings concerning the physiological, behavioral, and emotional consequences of travel impedance suggest that organizations and whole communities may be sustaining substantial "hidden" costs associated with conditions of transportation (e.g., in the form of increased disability claims, illness-related absence from work, and reduced levels of employee productivity and morale).

Behavioral Research as a Basis for Transportation Planning

The theoretical and policy implications of our findings suggest several potentially fruitful links among existing areas of research on transportation and behavior. Much of the existing literature on behavioral aspects of transportation can be grouped into two broad areas: (1) attitudinal analyses and market segmentation research aimed at increasing levels of ride sharing (e.g., by providing rapid transit facilities and corporate-sponsored commuting programs) within the community (cf. Hartgen, 1977; Horowitz & Sheth, 1976; Recker & Golub, 1976); and (2) experimental analyses and modification of transportation behavior (cf. Everett, this volume; Everett, Hayward, & Meyers, 1974; Everett, Studer, & Douglas, 1978). Our research on travel impedance and well-being (Novaco *et al.*, 1979; Stokols *et al.*, 1978) exemplifies a third, though perhaps less thoroughly examined, facet of the interface between transportation and behavior. In the remaining discussion, we suggest some potential links among these currently separate areas of investigation.

The findings from studies of transportation and well-being could provide an impetus for refining existing transportation services and a basis for encouraging individuals to make constructive changes in their commuting situations. Given that organizational personnel and community members in general may be sustaining health costs incurred through the demands of automobile driving, business corporations and government agencies might therefore be induced to provide more alternatives to the private automobile. In addition, research findings concerning the health consequences of impedance and the potential effectiveness of coping strategies for enhancing well-being illustrate the kinds of information that might be utilized in future informational and incentive-based campaigns aimed at persuading commuters to modify their travel behavior. Information regarding the health consequences of commuting patterns might increase the persuasive appeal of such campaigns, which, typically, have focused on economic and convenience factors, rather than on dimensions of physical and emotional well-being. As Everett *et al.* (1974) have speculated, physical technical advances might be accompanied by programs that address issues that are to a large extent behavioral in nature.

Our theoretical perspective incorporates the idea of environmental congruence, which refers to the degree to which a person's major goals are facilitated or constrained by environmental conditions. Previous studies of the attitudinal and behavioral underpinnings of ride sharing often reflect the assumption that increased citizen participation in collective transit is desirable. This assumption seems quite reasonable in view of the currently critical shortage of global fuel supplies. While increased levels of ride sharing may be necessary and desirable for societal well-being, virtually no research has been conducted on the health and behavioral consequences of participation in alternative forms of collective transit, particularly from the standpoint of person–environment fit.

The behavioral and health data furnished by studies of urban commuters could provide criteria for evaluating the cost effectiveness of organizational and community interventions designed to reduce rates of behavioral, emotional, and physical disorder. The identification of high-risk commuters, the provision of stress management programs and exercise facilities, changes in the structure of the work day, and transportation management strategies are among the intervention programs whose effectiveness might be enhanced by the findings from research on transportation and well-being.

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