

minimized within the complex of 17 variables used by the model. Interestingly enough, the most important variable in many cases is the age of the household. Unfortunately, the age of the housing units is not a policy variable. In fact, it is only a substitute variable denoting, most probably, the manner in which apartment buildings and other housing units were designed before 1940. A final point in this connection is that the model, as it is presented in the paper, does not always present results consistent with a priori presumptions. For instance, the households in apartment buildings built before 1940 whose workers are employed in central business districts (CBDs) have a lower probability for not owning an automobile than does a similar household in the rest of the region—the opposite of what would normally be expected for Phoenix and Boston in 1970.

Turning to the modal split model for home to work trips, the main strong points of this model are two. First is the separation into two steps and the emphasis placed on the three sociodemographic variables (income, age, size of household) plus the automobile ownership variable. In emphasizing the intrinsic significance of these variables for modal split, the model again offers, as in the case of automobile ownership, a distinct contribution. The second strong point of the modal choice model is the additional stratification of the workplace. The circumstances in both the origin and the destination of the trip play the major role in the choice of travel mode. The level of stratification the model includes and the manner in which it incorporates urban pattern variables need improvement if the model is to add to the present array of modal split models. In addition, the model would need to reach much higher levels of simulation accuracy to compete effectively with other models in the field. Finally, the policy variables (except, possibly, the rail dummy variable) appear to carry only marginal importance in the correlations produced. Again the expected probability of step one is the dominant variable, followed

in certain occasions by the old multiple apartment buildings variable.

COMMENTS AND REFLECTIONS

This paper has particular significance for both transportation and land use planners. It presents an innovative, intensive effort to develop new, predictive, and explanatory models for automobile ownership and modal choice. At the same time it explores in more depth the link between the transportation planner and the city planner. Although the title and some of the claims of the paper might be considered as somewhat unwarranted overstatements, the link between characteristics of the urban structure and the consumer patterns of urban residents is placed under central focus in the automobile ownership model. A similar link between urban structure and travel behavior centered on the most important component of urban travel, the home-to-work trip, is also attempted. What strikes me also as very important in these models is the two-step structure of the models and that the influence of the intrinsic characteristics of the household on automobile ownership and modal choice is emphasized first on a national scale, followed by the influence that some specific characteristics of each urban structure exert on automobile ownership and modal choice. Although in my view the models are not yet ready for widespread use, their contribution is clearly evident, especially with regard to the automobile ownership model. I hope that these and other researchers will continue the work in this field so that we may increase the hopes of establishing the frequently claimed but almost always elusive relationship between land use patterns and transportation.

Publication of this paper sponsored by Committee on Transportation and Land Development.

A Transit-Oriented City

Edward W. Walbridge, Department of Systems Engineering, University of Illinois, Chicago

Cities are designed to accommodate the automobile. A transit-oriented city is one that from inception is designed for public transportation modes rather than the automobile. In such a city, automobile use would be possible but unnecessary. The goal of a transit-oriented city is to make public transportation travel more attractive than driving so that automobiles will be little needed or used. One possible transit-oriented city is described. From this example we see that many of the advantages of current urban and suburban life-styles are attainable without automobiles. The building of a transit-oriented city as an experiment is suggested.

A transit-oriented city is designed to make automobiles little needed and little used; the movement of people is accomplished primarily by modes other than the automobile. Nonautomobile modes would include new and old types of mass transit, constant speed and accelerated

moving sidewalks, bicycles, and walking. A transit-oriented city would be an altogether new city (or town or new town-in-town) to be built from the ground up. Travel by automobile would be possible and, in fact, would not be deliberately discouraged. However, the design goal would be to make public transportation faster, safer, cheaper, more pleasant, and more convenient than automobile transportation, so that residents would choose to make most in-city trips by public modes. Public transportation of such attractiveness can be achieved through the integration of land use and nonautomobile movement technologies.

When a conflict occurs in the design of a transit-oriented city between the needs of automobiles (such as close-in parking or direct nonstop routes) and the needs of nonautomobile modes, the latter are given priority.

Similarly, the need for a pleasant urban environment is predominant over that for swift and convenient automobile travel. Except for these two priorities, automobile transportation is not hampered or restricted by artificially low speed limits or by the prohibition of automobile use at certain times, for example.

Transit-oriented cities offer, in the long term, a possible solution to the problems created by urban automobiles. These problems include air and noise pollution; accidents; congestion; excessive consumption of petroleum energy; excessive use of urban land; and unavailability to the poor, aged, handicapped, and young. The conventional approach to these problems is to improve automobiles. This approach is appropriate for the near term in existing automobile-dominated cities and towns. It is the approach that is being taken in the United States, where an effort is under way to make automobiles less polluting and more energy efficient.

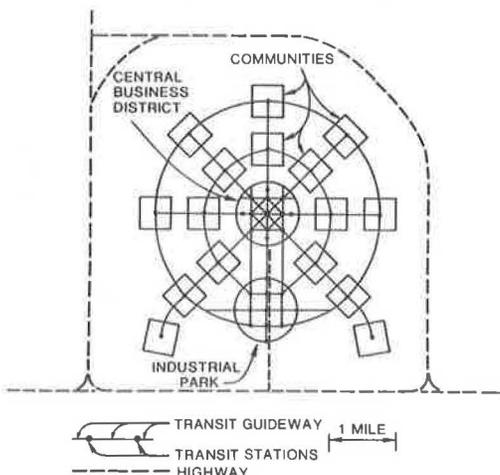
The transit-oriented city approach is appropriate for new cities, rebuilt parts of older cities, and new towns—and it is appropriate for the long term, by which I mean 20 years or more into the future. Transit-oriented cities offer alternative life-styles, which are not dominated by the automobile. These nonautomobile-dominated life-styles may be more attractive and cheaper than the automobile-dominated life-style available in contemporary cities and suburbs. Whether new life-styles can, in fact, be more attractive is especially important because of diminishing petroleum supplies.

A transit-oriented city must be designed so that automobile-related problems will not simply be replaced by other transit-related problems. A poorly designed transit-oriented city might suffer from people congestion in its transit vehicles and stations. A congested transit system can be avoided by carefully matching transportation capacity to transportation demand. The public transportation system in a transit-oriented city could be unduly costly and unduly consumptive of energy unless the city is designed to minimize the need for the movement of people. This can be accomplished by locating working, shopping, and other destination places close to living places. The importance of (a) minimizing the need for movement, and (b) matching transportation capacity to demand, have been pointed out by Wilfred Owen (1). Except for a few towns like Runcorn, England, no transit-oriented cities currently exist anywhere in the world.

EXAMPLE TRANSIT-ORIENTED CITY

Figure 1 shows a map of an example transit-oriented

Figure 1. The example transit-oriented city.



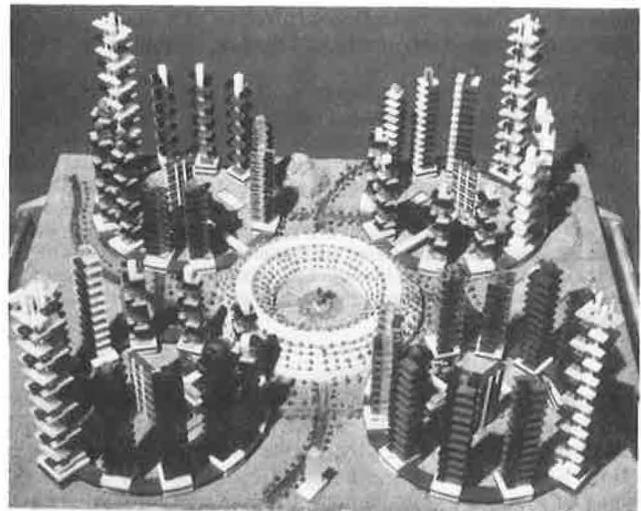
city. Each of the square-shaped figures is a cell or community, which has a transit station at its center. The two round areas are the central business district (CBD) (above) and an industrial park (below). Transit guideways (shown as lines) link the transit stations (shown as dots). Circumferential highways and an access highway are also shown.

Not shown are the local roads that thread through the CBD and the industrial park and connect these to the communities. The local roads are intended primarily for service and delivery trucks. The local road system requires indirect routes and is not designed for high speeds. There is limited room for automobile parking in the industrial park and none in the CBD. Automobile drivers destined for the CBD must park at lots on its perimeter and enter by foot. Once in the CBD they can move about by foot, by moving sidewalk, or by the transit system. In the CBD, the second-story level is the pedestrian level, one story above ground; trucks are restricted to ground level. People enter buildings and transit vehicles at the pedestrian level. The moving sidewalk system is on the pedestrian level and pedestrian bridges arc over the CBD's truck streets. The movement of people to and from the CBD and the industrial park is primarily by transit and only to a limited extent by automobile. The movement of goods to and from the industrial park, the CBD, and the communities is by truck.

Figure 2 shows a typical community. It is a picture of a model built by Victor Wong. The community consists of a central doughnut-shaped structure surrounded by four groups of buildings. In the center of the doughnut is a park, and under the park is the transit station. The exterior of the doughnut structure contains townhouses and apartments. The roof of each townhouse supports the yard of the townhouse just above. In Figure 2, one can see the trees in the townhouse yards. Inside the doughnut is a circular mall, which has a circular moving sidewalk running through it. Stores and offices are in the mall.

Consider the four groups of buildings surrounding the central doughnut-shaped structure. Each group consists of high-rise buildings whose bases are arranged in a circle and some lower-level buildings inside the circle. Each circle of high-rise buildings is connected near ground level by a flat ring-shaped structure (of blue plastic in the model). Inside this ring structure is a circular multilane moving sidewalk. The ring diameter is 274 m (900 ft, average

Figure 2. View of one community in the example transit-oriented city.



of exterior and interior diameters), or the size of three football fields.

Figure 3 shows, to large scale, one of the high-rise, ring-linked, buildings seen in Figure 2. The building is shown truncated in height. The Figure 3 high-rise building consists of living units, houses, stacked up in spiral staircase fashion around a central column. Each house looks out on its own yard, which is above the house one step down. A crawl space is between the top of the lower house and the floor that supports the soil of the upper house's yard. The houses are two-story units. As the sun changes position during the day, every yard will be at least partially exposed to direct sunlight. Another of the high-rise buildings seen in Figure 2 consists of single-story dwelling units. The buildings are extensions of the concept used by Moshe Safdie in his Habitat complex in Montreal (2).

High-speed elevators connect the houses to the ground level, where automobiles are parked, and to the level of the moving sidewalk, a circular multilane conveyor, shown in Figure 4. The Figure 4 moving sidewalk does not look circular because the picture is of a model that, for simplicity, was made linear. This type of moving sidewalk is contained inside each of the four blue ring structures. The outermost lane on the right is stationary, as is the outermost lane on the left. The lanes in between the two stationary lanes are all moving in the same direction, toward the observer. The wide lane in the center, which has the benches fixed to it, is the fastest lane. Lane speeds are symmetrically arranged on each side of the center lane. They increase progressively from the stationary lanes to the central lane, as shown by the arrows. The speed increment from one lane to the next is 0.8 km/h (0.5 mph). Thus, the outermost moving lane on the right moves at 0.8 km/h, the adjacent inner lane at 1.6 km/h (1 mph), and the next inner lane at 2.4 km/h (1.4 mph). The speed of the cen-

Figure 3. Large-scale, truncated in height view of the high-rise structures from Figure 2.

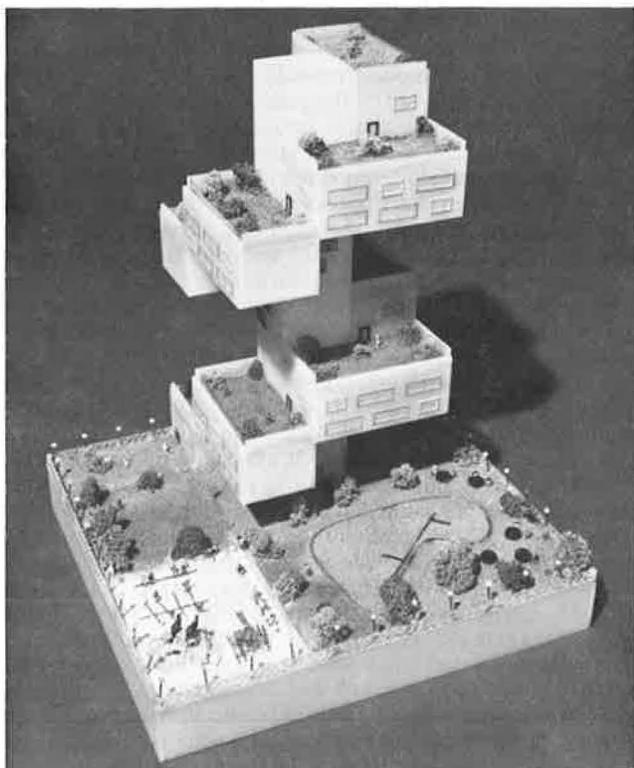


Figure 4. The multilane moving sidewalk in one of the four ring-shaped structures.



tral lane is 5.6 km/h (3.5 mph). If we add to this a typical walking speed of 4 km/h (2.5 mph), a pedestrian walking in the center lane would have a total speed of 9.6 km/h (6 mph).

Although 9.6 km/h is not very fast, it is sufficient because trip distances are short. At 9.6 km/h, a trip around one of the rings takes only 5½ min. By bus, one must walk to the bus stop and then wait for the bus to arrive; on this type of conveyor, one boards anywhere along its length without waiting.

As mentioned, the central doughnut-shaped structure also has a moving sidewalk running through it. The moving sidewalk in the central shopping mall and the four moving sidewalks in the rings are all on the same level. This is to facilitate local trips, especially for shoppers carrying goods. The doughnut's central park is on the level of the moving sidewalk, the third-floor level, and the transit station is on the second story level under the park.

Note the advantages of the circular configuration for a moving sidewalk. A person wishing to travel to an upstream destination can get there by moving downstream; a separate conveyor for each direction is unnecessary. Further, the lanes do not have to bend and so can be made rigid, yielding savings in mechanical complexity and cost over a linear conveyor of equal length. I discussed the advantages and disadvantages of multilane conveyors in another article (3).

The buildings inside each of the four blue rings are apartments, a school, perhaps a hospital, and offices. These buildings are connected by an all-weather pedestrian passageway to the central torus.

The Figure 2 community occupies an approximately square site about 0.7 km² (0.3 miles²) in area. The population of each community is about 8000 people, and the population of the entire city is about 140 000 people. In this city, the walking process would be assisted by moving sidewalks and escalators, and the pedestrian environment would be designed to make the walking experience pleasant and interesting. Along the pedestrian ways greenery, sculptures, and vistas through windows would entertain the stroller as he progressed.

The nature of the transit system that links the communities to each other and to the industrial park and CBD is indicated by Figures 5, 6, and 7. Station A (Figure 5) would be in one of the communities and station B in the CBD, for example. In this case, street level would

Figure 5. The transit system. Vehicles descend from and rise to the stations instead of having the pedestrians descend and ascend.

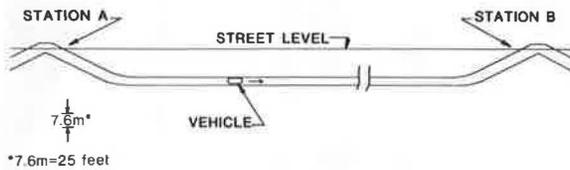


Figure 6. A vehicle rises uphill into an entrance-exit chamber (1), discharges and accepts passengers (2), and descends out of the chamber (3).

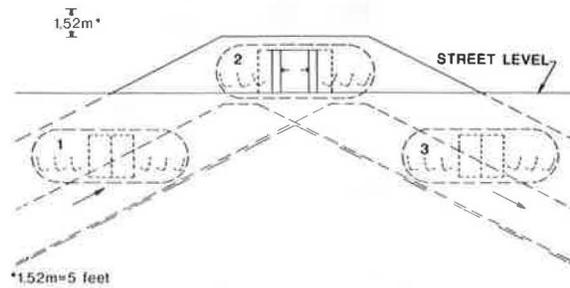
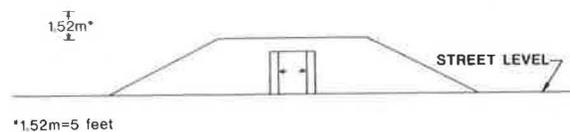


Figure 7. A transit user's view of an entrance-exit chamber.



be for station A, the transit station level, and for station B, the pedestrian level.

As shown in Figures 5, 6, and 7, the transit vehicles descend from stations at street level to below-grade tunnels or trenches. Thus stairways and escalators are not needed for access to the level of the tunnel or trench. Further, vehicles are accelerated by gravity as they go downhill from a station and decelerated by gravity as they rise uphill to a station. As a result, energy is not wasted in braking.

The transit vehicles would be activated by demand during times of low demand, functioning as horizontal automatic elevators; during periods of high demand they would depart at regular intervals on nonstop or one-stop trips. Maximum vehicle speeds would be in the 64- to 96-km/h (40- to 60-mph) range. Each transit station would have a number of vehicle entrance and exit chambers, such as the one shown in Figures 6 and 7, rising from its floor. This intercommunity transit system would be an automated guideway system.

ASSESSMENT

The example city is called transit oriented because it was designed to make transit travel more appealing than automobile travel. Whether this goal is actually realized in practice could be determined ultimately only by building the example city and populating it with residents.

A fundamental question is, Can our quality of life remain the same without automobiles? Perhaps life without automobiles may be even better than life with automobiles. If costs of the transit-oriented city are reasonable in the long run and if the quality of life is as good as it is now, if not better, then the implications are profound.

A necessary (but not sufficient) condition for a high quality of life in a transit-oriented city is that travel by public modes be more appealing than travel by automom-

bile. If this is not the case, too many residents will turn to the automobile; automobile congestion will be severe and automobile-created air pollution will not be avoided—in short, the quality of life will be degraded. The way to make public mode travel more appealing than automobile travel is to make the public modes faster (door-to-door), more convenient, safer, cheaper, and more pleasant than the automobile.

To see if the public modes are faster, consider travel times. The estimated door-to-door travel times by the public modes and by automobile are shown below for three trips in the example city (1 km = 0.62 mile).

Trip From a Home in a Ring High-Rise Building	By Public Modes	By Automobile
To the shopping mall in the central structure of the same community	4.7 min	5.2 min
To the CBD of the city (1 km from the origin community)	19.2 min	25.6 min
To a home in a ring high-rise building of another community (2.4 km from the origin community)	27.2 min	20.8 min

The trip times assume that the origin home is in a high-rise building attached to one of the blue rings, and that the high-rise building is located a maximum distance from the central doughnut-shaped structure. The times also assume that few travelers use automobiles. If many were to use automobiles, automobile trip times would increase significantly. Further, in developing the automobile times, the driver was assumed not to unlock his car to get in or to load packages or children, not to wear a seat belt, to start driving immediately after the engine is turned on, and to take less than 0.25 min to park (usually parking time is taken to be 1 min). So the given automobile times are lower limits.

Except for certain trips to the industrial area (those for which the trip maker has access to the few parking spaces within that area) and intercommunity home-to-home trips, the example city's public modes produce travel times that are as short as or shorter than those by automobile. The exceptional trips would be a small fraction of all trips. Thus, for most of the trips in the example city, the public modes are as fast as or faster than private automobile travel.

In the example city, the public modes appear to be at least as convenient as the automobile. They provide rapid, zero-fare service at any time of the day or night, and are accessible from the home without going outside. The traveler on the Figures 5, 6, and 7 transit system gains direct access to the core of activity centers (the CBD or community centers), whereas the automobile traveler must park, often take stairs or an elevator to change levels, and then enter an activity center from its periphery. Children can use the moving sidewalks without the aid of adults. Thus, the need for busing to schools and chauffeuring to extracurricular activities would be eliminated. The example city's public movement system would be designed and operated to provide safer transportation than that available by automobile.

The nonautomobile modes in the example city would be zero-fare systems. This is equitable if most people use public transit rather than automobiles, and such a policy saves users' time and the costs of fare collection. The cost of providing public transportation in the example city is difficult to assess. The three-station personal rapid transit (PRT) system in Morgantown, West Virginia was built at a cost of \$60 million, of which \$24 million was for research and development (4). Clearly, the cost of the example city's public movement systems would be great, but so too would be the savings due to reduced automobile costs. These savings would prob-

ably amount annually to \$1000 or more for each family. The example city would house about 45 000 families, so total annual savings for these families would be \$45 million.

Residents of the example city would find the non-automobile modes more pleasant than driving, assuming there were no threat of crime on the public system and that city residents did not value the privacy of the automobile. Given this situation, would the great majority of trip makers in the example city find the nonautomobile modes more appealing than the automobile?

It is appropriate to seek guidance from existing modal-split models. For the example city, the Washington-Toronto-Philadelphia model (5, 6, 7) predicts that 82 percent of work trips will be made by transit, assuming that all trip makers are in the highest of the model's five income ranges. However, neither this nor any other existing modal split model can make reliable transit-share predictions for the example city. This is because a trip maker's decision to travel by the non-automobile modes or by automobile reflects his subjective perceptions of the two alternatives, and in the example city the nonautomobile mode travel experience and the experience of automobile travel would both be radically different from the corresponding experiences in existing cities. Transit shares predicted by existing models will be too low. Probably, the transit share of trips in the example city will be sufficiently high, and the automobile share sufficiently low that automobile usage will cause little environmental degradation. Assuming this, an important condition for a high quality of life in the city would be met. There is one other condition, namely that example city residents must find the non-transportation aspects of their city attractive. I feel that this second condition would also be met because the city provides suburban privacy and greenery in the context of urban variety. In my judgment then, the quality of life in the example city would be high. With a high quality of life and an attractive life-style, the example city offers the good life without automobiles. Can the good life without automobiles be even better than the automobile-dominated version thereof (that is, similar to suburbia with two automobiles in every garage) that we have today? Perhaps.

Besides the example city, there are other possible types of transit-oriented cities. Intracommunity transportation could be provided by pedestrian passages, bicycles, horizontal elevators, or electric minicars instead of by moving sidewalks. Types of intercommunity transit could be used that would be different from the type shown in Figures 5, 6, and 7. Housing need not be stacked up spiral staircase fashion, for example.

Automobiles are not the only route to the good life. Indeed, the quality of life without automobiles, in transit-oriented cities may be even better than the quality of life with automobiles. Or, if not better, perhaps more affordable in a petroleum-hungry and space-limited world. But the question of costs is outside the scope of this paper.

A Suggestion

I want to suggest the building of an experimental transit-oriented city in the United States. It should not be identical to the example city, however; better designs are possible. A transit-oriented city would be a transportation energy conserving city; each person would require perhaps as little as 10 percent of the transportation energy now required in existing cities. In view of this and other advantages, new cities and rebuilt parts of old cities should be transit oriented rather than automobile oriented. Such an experiment would be expensive, costing

between \$5 and \$50 billion, but going to the moon was also an expensive experiment.

The suggestion that an experimental city be built is not new. Athelstan Spilhaus put forward the idea of such a city in 1968 in *Science* (8). In a 1971 article in *Saturday Review*, Anthony Downs suggested the building of a transit-oriented city as an experiment (9). He stated: "Full-size autonomous new cities offer our best change to try alternative urban forms that might reduce key problems (such as designing a city mainly for public transit to cut air pollution and traffic congestion)." Actually, Runcorn, England, is already an experimental transit-oriented city (10). I am suggesting a more technologically innovative version for the United States.

There is no reason why a city experiment should be limited in scope to transportation and land use; new solid waste disposal technologies and solar energy technologies could be evaluated as well. Indeed, new social and institutional arrangements could also be tried out. Root causes of crime could perhaps be eliminated; new welfare programs could be tested, and an attempt made to eliminate the alienation and loneliness of American society described by the sociologists Bronfenbrenner (11) and Slater (12).

ACKNOWLEDGMENTS

I am grateful to the University of Illinois at Chicago Circle and the Sierra Club Foundation of San Francisco for their support of the model building efforts required by this research, and am further grateful to my students, Victor Wong and Irwin Matten, for their fine work in constructing the models.

REFERENCES

1. W. Owen. *The Accessible City*. Brookings Inst., Washington, DC, 1972.
2. M. Safdie. *Beyond Habitat*. MIT Press, Cambridge, 1970.
3. E. W. Walbridge. *Multilane Passenger Conveyors*. *Transportation Engineering Journal*, ASCE, Vol. 101, No. TE3, Aug. 1975, pp. 463-477.
4. R. J. Hartman. *Moving People in Morgantown: A Special Report*. *Passenger Transport*, Vol. 34, No. 1, Jan. 2, 1976, pp. 1, 4-5.
5. M. Wohl and B. V. Martin. *Traffic Systems Analysis for Engineers and Planners*. McGraw-Hill, New York, NY, 1967.
6. J. W. Dickey. *Metropolitan Transportation Planning*. McGraw-Hill, New York, NY, 1974.
7. D. M. Hill and H. J. VonCube. *Development of a Model for Forecasting Travel Mode Choice in Urban Areas*. HRB, *Highway Research Record* 38, 1964, pp. 78-96.
8. A. Spilhaus. *Experimental City*. *Science*, Vol. 159, Feb. 16, 1968, pp. 710-715.
9. A. Downs. *Private Investment and the Public Weal*. *Saturday Review*, May 15, 1971, p. 24ff.
10. L. Hoel. *Public Transport Innovations in Principal European Cities*. Carnegie-Mellon Univ., Pittsburgh; Urban Mass Transportation Administration, May, 1973; NTIS, Springfield, VA, PB 221 419.
11. U. Bronfenbrenner. *The Origins of Alienation*. *Scientific American*, Vol. 231, No. 2, Aug. 1974, pp. 53-61.
12. P. Slater. *The Pursuit of Loneliness*. Beacon Press, Boston, 1970.