Transportation in Developing Countries: Obvious Problems, Possible Solutions

C. JOTIN KHISTY

Solving transportation problems is one of the chief tasks confronting governments in developing countries. Despite large expenditures on urban transport systems, ranging from 15 to 25 percent of their total annual expenditures, the current problems have not eased; on the contrary they seem to get worse. Developing countries, therefore, have a major crisis on their hands. The scale and nature of the mobility problem in the Third World and the role of nonmotorized and intermediate-type motorized modes in meeting the mobility needs of the growing population are discussed. Background on the transportation situation in developing countries is provided. The prevailing transport policies are examined, and the basic characteristics of nonmotorized and intermediate-type motorized transportation with respect to speed-distance-time relationships are described. City size and city form vis-à-vis nonmotorized transport are examined. What constitutes a good environment for nonmotorized and intermediate motorized modes is discussed, and transport projects that would benefit the poor are described.

Regardless of how we view the future, we cannot ignore it, for as Harmon reminds us, it is where we are going to spend the rest of our lives (*1*). It is useful then to start our discussion by considering the size and nature of the mobility problem confronting developing countries. Urbanization is occurring all over the world, and the most reliable forecasts indicate that by the turn of the century almost half of humanity will live in urban centers. The rate of population growth in the developing countries is 2.5 percent per year as opposed to 1 percent in the developed world, and this disparity is phenomenal. Just over the last 65 years, the developing world's urban population has increased 10-fold, from around 100 million in 1920 to 1 billion in 1985. And between 1985 and 2000, cities in the Third World are very likely to grow by another three-quarters of a billion. These figures suggest that developing countries must increase their capability to supply and effectively manage their urban infrastructure by at least 75 percent merely to maintain their current level of service, which, to say the least, is woefully inadequate (*2*). Solving transport problems has thus become one of the chief tasks confronting governments in the developing countries. Despite large expenditures on urban transportation systems, ranging from 15 to 25 percent of their total annual expenditures, the current problems have not eased; on the contrary they seem to get worse. Indeed, few city governments in the developing world have the power, resources, and trained personnel to provide adequate services to improve the current situation. Developing countries, therefore, have a major urban crisis on their hands (*2,3*). A majority of developing countries cannot provide sufficient investment in public transportation to keep up with population growth, and even if such transport were provided, a large proportion of the poor would not be able to afford it. The poor can only afford to walk or bicycle (*4,5*).

This paper focuses on modes of transportation and relevant projects that directly help the poor in developing countries, and therefore the major focus is on nonmotorized modes. The paper provides a brief background of the transportation situation in developing countries; examines the transport policy implications of developing countries; describes the basic characteristics of nonmotorized transportation, in particular the speed-distance-time relationships; examines city size and city form vis-à-vis nonmotorized transportation; investigates what constitutes a good environment for nonmotorized and some intermediate motorized modes; and describes transport projects that would benefit the poor.

Department of Civil Engineering, Illinois Institute of Technology, Chicago, Ill. 60616.

BACKGROUND

The importance of transportation lies chiefly in its contribution to the large economies of scale and specialization associated with urban areas. Transportation facilities expand the options for work, education, health, and other amenities and directly affect the economic efficiency of cities and the well-being of their inhabitants. Provision of the minimum transportation facilities within the various limited resources available is the most critical problem in developing countries.

However, other aspects of transportation need to be noted. Transportation modes used in developing countries around the world are highly diverse. It is estimated that 600 million person-trips a day are made by city buses and that a similar number are made by rail and rural buses. A quarter of a billion trips are made by 50 million automobiles. In contrast, several billion bicycle trips per day are made by well over half a billion bicycles in developing countries, and daily pedestrian trips exceed 10 billion per day (*3*).

The frequency and choice of a mode depend on such diverse factors as infrastructure design, topography, climate, socioeconomic conditions, income levels, land use patterns, subsidies, taxes, and tariff policies. However, everybody is affected by acute transport problems, particularly because of the scarcity and the high cost of transportation. The proportion of income spent by the poor on transportation is about 1/10 of their total income. Naturally, the proportion of trips made on foot and by bicycling is high. Although alternative transport is available, the urban poor in developing countries must resort to nonmotorized modes. The concept of the value

of time and the utility of time savings is generally not a significant factor for the poor and is put into practice only in emergencies (*6,7*).

TRANSPORTATION POLICY IMPLICATIONS

It may come as a surprise that most developing countries do not have a stated policy on passenger mobility per se. The main focus is on the movement of freight traffic to fulfill output targets set by the countries in their 5-year plans. When transportation projects are planned and budgets allocated for implementation, little attention is paid to passenger travel. This policy has led to a progressive deterioration of traffic conditions for practically all modes of passenger transport in developing countries. Most ironically, developing countries seem to focus on encouraging motorization and appear to be indifferent or even opposed to low-cost, nonmotorized modes, despite the vital role they play in the local economies and the mobility and accessibility they provide for low-income inhabitants (*5*).

Even when it comes to transportation planning, developing countries generally adopt the methodologies conventionally practiced by developed countries, and the results have been very discouraging (*8*). Prud'homme (*9*) confirms this craze in developing countries for using the questionable classical set of models, used in the Western world, based on the concept of quantifying trips instead of critically considering in their analysis such items as poverty, human fatigue, cultural values, and equity.

NONMOTORIZED TRANSPORT CHARACTERISTICS

The degree of motorization in developing countries is associated with the level of income of a city (and the country it is located in). A strong relationship exists between the average per capita income in a developing country and the number of automobiles per thousand population. According to recent estimates, walking trips account for two-thirds of the total trips in large African cities such as Dar es Salaam, and walking and cycling trips account for between 40 and 60 percent of the total trips in several large cities on the Indian subcontinent (*10*).

The predominance of the nonmotorized modes should come as no surprise; they are some of the most efficient. Examination of the capacities of modes indicates that a sidewalk can carry more people per foot width per hour than any other form of track except exclusive bus lanes or rail track (about 1,100 can be accommodated at a speed of about 2 mph). Low speeds and fatigue can of course limit walking trips to about 2 to 3 mi. However, the demand for walking trips is the highest. Bikeways are also relatively inexpensive and yet efficient. At speeds of about 8 mph, the capacity of bikeways can reach 450 per foot-width, or 1,800 persons per bike lane, which easily exceeds that of automobiles and equals that of fully occupied buses. Thus, bikeways offer a great potential for developing countries (*3*).

SPEED-DISTANCE RELATIONSHIPS

Transportation planners are well aware of the high correlation between trip length and the demand for speed in people's daily experiences in choosing a mode of travel. For example, in the developed world it has been observed that when the time of travel is doubled, the distance covered increases 10-fold, whereas the speed increases 5-fold (*11*). Planners are cognizant of the "refusal" distance of an average pedestrian, who will not choose to walk more than 400 m (or ¼ mi). Beyond 400 m the majority of pedestrians in North America would demand some type of mechanical system to transport them. But, since bicycling or riding a bus is not popular in the United States, the pedestrian in our case is most likely to hop into a car to cover the distance! There is ample evidence that the trip maker's choice of mode is not based on cost alone, but also on travel time; subconsciously, distance is connected with time. Research conducted by Kolbuszewski (*12*) and Khisty (*13*) has resulted in simple relationships connecting T, the time of travel (min), d, the distance covered (km), and v, the speed (km/hr): $T = 6.6d^{0.30}$ and $d = 0.043v^{1.42}$. This phenomenon generally produces the three dominant modes in the Western world: walking for short distances, driving a car for medium distances, and the airplane for long distances. This dominance also produces several "transportation gaps." Table 1 indicates how the three dominant modes take care of the entire spectrum of transport in the developed world, particularly the United States.

The transportation modal hierarchy in the developing world is radically different from that of the developed world. Whereas time is certainly equivalent to money, a reduction in travel time means an increase in speed; and speed costs money. But since the average income of developing countries is low, the speed-distance relationship depends heavily on the perceived relative value of time, which again depends on cultural, social, and economic characteristics of the population.

A comparison of some of the principal modes of travel available in developed and developing countries, based on time (T), speed (v), and distance (d) parameters, is given in Table 2. The most striking conclusion from this comparison is that the value of time in developing countries in general is not as crucial as that in developed countries. For example, whereas the "refusal" distance of the walking mode in developed countries is 0.4 km (¼ mi), the corresponding distance for developing countries is 2 km (1.25 mi). Similar ranges for the bicycle mode are 1.5 km and 9 km.

TABLE 1 Transport Distance-Speed-Time Functions for the Developed World

Distance (km)	Time (min)	Theoretical Speed (km/hr)	Mode Alternative
0.4	5.0	5	Walk
1.0	6.6	10	Bicycle[a]
4.0	10.0	25	Car, bus[a]
10.0	13.2	50	Car
40.0	20.0	120	Car
100.0	26.4	225	Car
400.0	40.0	600	Small plane
1000.0	52.8	1125	Jet

[a]This mode used by a very small percentage.

TABLE 2 Comparison of Modes in Developed and Developing Countries in Terms of Time/Speed/Distance

Modes	Developed			Developing			Countries: Indonesia			Countries: India			Ownership	Person Capacity per meter width/hr
	Speed (km/hr) v	Dist (km) d	Time (min) T	Speed (km/hr) v	Dist (km) d	Time (min) T	Speed (km/hr) v	Dist (km) d	Time (min) T	Speed (km/hr) v	Dist (km) d	Time (min) T		
Non-Motorized														
Walk	5	0.4	5	4	2	30	5	2	25	5	2.5	30	Personal	3600
Bicycle	12	1.5	7.5	12	9	45	12	9	45	11	5.5	30	Personal	1500
Bicycle-Rickshaw (3-wheel)	--	--	--	8	4	30	8	4.5	35	8	4	30	For hire	Variable
Motorized														
Scooter	25	4	10	20	10	30	25	30	75	20	10	30	Personal	100-200
Auto														
City	25	4	10	20	20	60	25	30	75	20	20	60	Personal	120-220
Arterial	50	11	13	65	130	120	50	102	120	65	130	120	Personal	750
Freeway	80	22	16.5										Personal	
Bus														
City	18	2.5	8.5	12	12.5	60	18	18	60	17.5	5.0	17.2	Public	2700
Express	80	22	16.5										Public	5200
Auto-Rickshaw (3-wheel)	--	--	--	20	20	60	20	22	65	20	20	60	For hire	Variable
	$T = 6.6d^{0.30}$ $d = 0.043v^{1.42}$			$T = 19.74d^{0.36}$ $d = 0.22v^{1.48}$			$T = 18.34d^{0.41}$ $d = 0.12v^{1.70}$			$T = 13.57d^{0.45}$ $d = 0.14v^{1.56}$				

What this shows is that nonmotorized modes—walking and bicycling—in developing countries offer a much wider trip-length range, and this fact by itself emphasizes their importance. In India, for example, as in several other developing countries, a variety of transport modes fill the gap between walking and the private car, and the distance range afforded by this variety needs to be taken advantage of in providing the transportation network and city form. Note that bicycles, bicycle-rickshaws, scooters, and other intermediate technology vehicles are ubiquitous in most developing countries, providing the needed mobility and accessibility in terms of the prevailing socioeconomic and cultural circumstances. Also, it is evident that the urban use of the automobile is inappropriate to its intrinsic speed, power, and size characteristics and has unfortunately led to a number of serious problems.

CITY SIZE AND CITY FORM

In almost all Third World countries, ideas about land use and transportation planning are firmly rooted, and, unfortunately, motorization is still seen as a key indicator of economic progress (*14*). It is remarkable that in the last 1,000 years, planners have been discussing the optimum size of a city and have ironically come up with a broad range for a city from about 50,000 to about 200,000 population. From a sociological standpoint, smaller cities outperform larger ones in any number of social variables such as absence of crime, health, mental health, recreation, and education. Economically, annual expenses per capita for a city of 1 million are 300 percent greater than for a small city of 50,000 to 100,000 (*15*). From a transportation viewpoint it is well known that the quantity of movement (person-miles traveled or ton-miles transported) grows geometrically as city size increases (*16*). Trip lengths vary from about 2 mi for a city of 50,000 to about 6 mi for one of 1 million. The important fact is that more trips have to be made by motorized means as city size increases, resulting in proportionally higher operating costs. It has therefore been proposed, time and again, that the growth of population and economic activities should be shifted from large agglomerations to small and medium-sized cities. Maunder's research indicates that restructuring of land use by locating the place of work as close as possible to the workers' residences (or vice versa) could lead to a 30 percent reduction in the number of trips by bus and over a 100 percent increase in trips by bicycle and walking (*17*). Another way of reducing trip lengths is by not having single-function zones. Single-function zones result in excessively long trips, not to mention excessive energy consumption and adverse environmental impacts. Thus, mixing residential, commercial, and certain low-pollution industrial land uses improves mobility and access to employment opportunities for the low-income population, which relies solely on nonmotorized transportation (*18*).

WHAT CONSTITUTES A GOOD ENVIRONMENT FOR NONMOTORIZED TRANSPORT?

Since walking is the dominant mode in developing countries and is influenced by trip length, weather, and the availability and cost of alternative modes, pedestrians need safe, comfortable, direct, and accessible routes covering the city. Enhancing the pedestrian domain involves reducing travel distances; increasing land use flexibility; eliminating pedestrian barriers and obstacles; leveling walking routes; ensuring continuity of travel; providing protection from wind, rain, noise,

cold, heat, and pollution; eliminating conflict with other modes of travel; and increasing character through visual diversity and amenity. This list may seem at first sight to be unrealistic, but the objectives are justified by the fact that in hundreds of cities in the developing world almost 50 percent of the trips are made by walking, not for keeping fit, but primarily because of poverty. Imagine, for a moment, how different these cities would be today if 50 percent of all funding allocated for transportation improvement (in proportion to pedestrian usage) were used to improve the pedestrian domain! Local climatic conditions should be reflected in the detailed planning and design of sidewalks and routes used by pedestrians because a large majority of pedestrians will be among the poorest and most debilitated of the poor. For them, the shortening of trip lengths and provision of reasonable walking comfort should be considered not just as matters of convenience but as factors affecting basic productivity (*8,19*). The advantages of walking and bicycling relative to other modes have long been recognized and include absence of capital costs for vehicles, absence of any foreign exchange requirements, and the need for very inexpensive infrastructure.

The bicycle is one of the most convenient and energy efficient forms of individual transport. It is available to everybody, especially the poor, because costs are low for both the user and the government. Operating cost per bicycle-mile is lower than for walking because of the value of time. Bicycle use can be easily encouraged by providing lightly surfaced paths parallel or adjacent to local streets. Simple parking structures with bicycle racks can be provided in center city locations. In some cases, where the demand for bicycling warrants it, exclusive bike lanes may be provided, and this kind of construction may be an excellent means of preserving future rights-of-way for an expanded transportation network (*20*).

Although most cities in developing countries lend themselves to bike commuting, bicycles in general do not perform well on streets having gradients in excess of 3.5 percent or on poorly surfaced roads. The fact that most bicycles in the third world are equipped with only single gears calls for particular attention to good surface conditions. Separate bikeways for high-demand corridors is probably the best solution.

The bicycle rickshaw, pedicab, or "becak" is essentially a nonmotorized mode of public transport. These pedal-powered vehicles constitute a predominant element in the street traffic of cities like Dacca, Bangladesh, and account for both passenger and goods movement. In India, Pakistan, Thailand, Indonesia, and other countries around the world the rickshaw has attained similar importance. It is an economical vehicle and fills a valuable role in the nonmotorized hierarchy because of the following characteristics: (a) its low capital cost and easy licensing arrangement are a source of employment for the poor; (b) its size allows this three-wheeler to negotiate narrow streets and alleys and other areas of the city where few vehicles would be able to go; and (c) its versatility allows it to carry produce to market, children to school, and commuters to work (*5,20*).

The three-wheeled bicycle rickshaw has been thoroughly studied by researchers from the socioeconomic and transportation points of view. The general conclusion is that this form of transport provides a flexible and personalized service (*5,21,22*). Also, the manufacture, maintenance, and operation of these vehicles provide a steady supply of employment to workers ranging from highly skilled to unskilled. Improvement of the rickshaw through the addition of a motor has advantages discussed later in this paper. Bicycle rickshaws require a smooth riding surface and grades not exceeding 2 percent; motorized rickshaws are able to handle grades up to 3 percent (*20*).

Animal-drawn and human-powered carts (handcarts) are an important part of the nonmotorized spectrum of vehicles plying the roads and streets of developing countries. Because they require low capital investments, the cost of haulage of goods by this mode is often competitive with (and at times cheaper than) mechanized transportation. Their unit capacities make them relevant for small-scale operation at ports, warehouses, shopping centers, and other terminals. In addition to being able to withstand low standards of road surfaces, they are able to access narrow alleys and lanes in densely populated areas of the inner city. Despite their low speed, they serve a useful function.

OTHER TRADITIONAL MOTORIZED MODES

Whereas traditional modes bear a variety of local names, according to nationality, they generally provide adaptable forms of transportation at relatively low capital cost. The production, maintenance, and repair of these vehicles also provide a useful source of low-skilled employment. In some respects these traditional modes resemble bicycle usage, because they serve widely dispersed destinations and can be readily adapted for use in various environments (*20*). The key to effective urban transportation, particularly in developing countries, is flexibility, and the most striking feature in southeast Asian cities is the variety of transportation modes, particularly vehicles with two, three, or four wheels that supplement and complement pedestrian travel. These vehicles, called variously helicaks, minicars, bemos, mebeas, autorickshaws, four-seaters, tempos, cycle-motors, lambros, and samlors, offer a range of technological sophistication. Most of these transport forms have arisen spontaneously in response to social needs, illustrating the diversity of solutions available to the problem of moving people and freight around a city with a minimum of resources. This is an example of the effective adoption of appropriate technology that is ideally suited to these societies, because the marginal cost of additional transportation capacity is small for the entrepreneur and, for the government, often nothing. Therefore, intermediate motorized modes need to be encouraged and may possibly lead to the future deemphasis of private automobiles (*8,23*).

PROJECTS AND MODES THAT AFFECT THE POOR

The fact that a large sector of the population of developing countries cannot afford any form of motorized transportation underlines the necessity of providing facilities for nonmotorized travel. Attention should therefore be placed on projects that provide transportation directly to the urban poor. It may be useful to begin by considering the purpose of transport projects that will benefit the poor: (*a*) to provide jobs and

accessibility to jobs, (*b*) to distribute essential commodities used by the poor and to keep the distribution cost as low as possible, (*c*) to facilitate access to essential urban services, (*d*) to facilitate social interaction, (*e*) to increase the supply of land suitable for settlement by the poor, and (*f*) to allocate land use so that the average trip length is as short as possible and can be accomplished by nonmotorized transportation as far as possible (*20*).

With the scarcity of resources available, it may be highly improbable that major road projects will be undertaken. Instead, there is the possibility of small projects that can help improve conditions for the poor almost immediately, such as paving improvements, minor changes to road geometrics, widening of streets and lanes, and addition of sidewalks or bicycle lanes. Streets in urban areas of developing countries are generally used for a wide variety of purposes. Contrary to views of utility in the West, where nonmotorized transport is considered to belong to the nuisance category, multiple uses of street space, particularly where light traffic prevails, should be viewed as an efficient use of public capital. All road improvement projects need to be analyzed to reflect the variety of functions served by street space, including right-of-way space. This analysis would help uncover methods of encouraging employment of the poor in construction and maintenance of the roadway and accompanying facilities. Pedestrian and bicycle movements on and across major streets should be controlled through proper placement and enforcement to increase the safety of nonmotorized traffic.

In improving existing or proposed facilities for nonmotorized transport, three aspects of planning should be kept in mind: (*a*) the general nature of non-Euclidean metrics, as opposed to Euclidean metrics (which is the length of the shortest possible path joining a pair of points), (*b*) the sensitivity of nonmotorized movement to delay and hazards on account of motorized traffic, and (*c*) the use of plastic space (i.e., the relationship between time space and geographic space) in exploring efficient forms of spatial organization and reorganization. These ideas have been addressed in detail in recent literature (*24–26*).

In summary, cost-effective transportation system management strategies can improve mobility and accessibility and reduce accidents. The question that almost always arises is, should one repair, rehabilitate, reconstruct, or replace existing facilities? These decisions should be based on evaluations of life cycle considerations and costs, preferably early in the life of a transport system, because these evaluations influence the entire useful life of the facility and determine its true cost to the public (*27*).

CONCLUSIONS AND RECOMMENDATIONS

Urban transportation planning in developing countries is still in its infancy, and criteria for identifying appropriate planning methods and formulating appropriate projects are urgently needed. The scarcity of resources and the mounting pressure to provide transportation facilities to a rapidly growing urban population require that major changes be made in priorities for selecting projects for the urban poor. Changes are also needed in transportation policy making in developing countries. Opportunities still exist to achieve resource-efficient transportation service without resorting to capital-intensive projects. The following recommendations are worth considering:

1. Attention should be paid to the distance-time-speed relationships prevalent for nonmotorized and some intermediate-type motorized modes. Energy and road capacity issues connected with these modes should be critically examined.
2. City size, city form, and issues connected with mixed land use need to be kept in mind, considering the fact that the distance ranges of nonmotorized modes are far more flexible in Third World countries than in the developed world.
3. Projects that fall under the rubric of transportation systems management (i.e., construction, operation, and institutional tasks to make the most productive and cost-effective use of transport facilities) should be undertaken, particularly those benefiting the poor.

REFERENCES

1. W. Harmon. *An Incomplete Guide to the Future*. W. W. Norton, New York, 1979.
2. World Commission on Environment and Development. *Our Common Future*. Oxford University Press, 1987.
3. *Urban Transport Policy Study*. The World Bank, Washington, D.C., 1986.
4. C. J. Khisty. Facing the Realities of Non-Motorized Transportation in Developing Countries. *Journal of Advanced Transportation* (forthcoming).
5. M. A. Replogle. Sustainable Transportation Strategies for Third World Development. In *Transportation Research Record 1294*, TRB, National Research Council, Washington, D.C., 1991.
6. *Global Report on Human Settlements*. United Nations Center for Human Settlements, Nairobi, Kenya, 1987.
7. V. S. Pendakur. Planning for Pedestrians in Kathmandu, Nepal. *Proc., 5th World Conference on Transportation Research*, Yokohama, Japan, 1989.
8. C. J. Khisty. Research on Appropriate Planning Methodology in Developing Countries. In *Transportation Research Record 1028*, TRB, National Research Council, Washington, D.C., 1985.
9. R. Prud'homme. Urban Transport in Developing Countries: New Perceptions and New Policies. *Proc., 5th World Conference on Transportation Research*, Yokohama, Japan, 1991.
10. J. F. Linn. *Cities in the Developing World*. Oxford University Press, Oxford, United Kingdom, 1983.
11. G. Bouladon. The Transportation Gap. *Ekistics*, Vol. 25, 1968.
12. J. Kolbuszewski. How Decisions in Transportation Safety Will Ultimately Be Taken. *Transportation Safety Proceedings*, Institute for Safety in Transportation, San Diego, Calif., 1979.
13. C. J. Khisty. *Transportation Engineering: An Introduction*. Prentice-Hall, Englewood Cliffs, N.J., 1990.
14. S. Gibbons. Urban Land Use and Non-Motorized Transport in Kanpur, India. In *Transportation Research Record 1294*, TRB, National Research Council, Washington, D.C., 1991.
15. K. Sale. *Human Scale*. Coward, McCann and Geoghegan, New York, 1980.
16. Y. Zahavi. *Travel Characteristics in Cities of Developing and Developed Countries*. Staff Working Paper 230. The World Bank, Washington, D.C., 1976.
17. D. A. C. Maunder. *Households and Travel Characteristics in Two Residential Areas in New Delhi, India*. TRRL Supplement Report 673. Crowthorne, United Kingdom, 1981.
18. W. Suchorzewski. Human Settlement Pattern and the Need for Transportation. *Proc., 5th World Conference on Transportation Research*, Yokohama, Japan, 1989.
19. R. K. Untermann. *Accommodating the Pedestrian*. Van Nostrand Reinhold Co., New York, 1984.

20. J. D. Herbert. *Urban Development in the Third World: Policy Guidelines*. Praeger Publishers, New York, 1979.
21. P. J. Rimmer. Structure, Conduct and Performance of the Rickshaw Industry in East and South East Asian Cities. *Proc., 5th World Conference on Transportation Research*, Yokohama, Japan, 1989.
22. B. T. S. Soegijoko. *Intermediate Public Transportation for Developing Countries: Case Study of Bandung, Indonesia*. Ph.D. thesis. Massachusetts Institute of Technology, Cambridge, 1982.
23. A. K. Meir. Bekaks, Bemos, Lambros, and Productive Pandemonium. In *Planning for Small Enterprises in Third World Cities* (R. Bromley, ed.), Pergamon Press, Oxford, United Kingdom, 1985.
24. C. J. Khisty. Non-Euclidean Metrics in Non-Motorized Transportation. In *Transportation Research Record 1281*, TRB, National Research Council, Washington, D.C., 1990.
25. C. C. Wright. Geometric Delay to Pedestrians. *Transportation Research A*, Vol. 19A, No. 3, 1985.
26. P. Forer. A Place for Plastic Space. *Progress in Human Geography*, No. 3, 1978.
27. D. Novick. Life-Cycle Considerations in Urban Infrastructure Engineering. *Journal of Management, ASCE*, Vol. 6, No. 2, 1990.