1994

Urban Transportation - A Special Challenge for Civil Engineers

Vukan R. Vuchic
University of Pennsylvania, vuchic@seas.upenn.edu

Recommended Citation

Vukan R. Vuchic, "Urban Transportation - A Special Challenge for Civil Engineers", *Proceedings of International Symposium Organized by Japan Society of Civil Engineers in Commemoration of Its 80th Anniversary* , 275-290. January 1994.

Urban Transportation - A Special Challenge for Civil Engineers

Abstract
Transportation has historically had a major influence on cities - their locations, growth and form. Civil engineers were the leading public servants in construction of railway and transit systems. With diversification of transportation and, particularly, growth of highways, the solutions to urban transportation have become extremely complex. Instead of only building new facilities, it is now necessary to coordinate different modes.

Planning of transportation is defined at four levels: individual facilities, single mode networks, intermodal systems and city-transportation relationships. It is shown that the latter two levels have not been adequately performed. Coordination of systems must be given greater attention. A brief review of successes and failures in urban transportation in different countries, with particular emphasis on Japan, is given at the end. The transportation and civil engineers' roles should change to include a much greater emphasis on systems approach in planning, design, operation and policy. It is particularly important that engineers give attention to the methods for achieving efficient and attractive cities.

Disciplines
Engineering | Systems Engineering | Transportation Engineering

Proceedings of
International Symposium organized by Japan Society of Civil Engineers
in commemoration of its 80th Anniversary

CIVIL ENGINEERING
FOR
URBAN DEVELOPMENT AND RENEWAL

Issues and Prospects of Technologies in Civil Engineering

Japan Society of Civil Engineers

URBAN TRANSPORTATION-
A SPECIAL CHALLENGE FOR CIVIL ENGINEERS

Vukan R. Vuchic[1]

ABSTRACT

Transportation has historically had a major influence on cities - their locations, growth and form. Civil engineers were the leading public servants in construction of railway and transit systems. With diversification of transportation and, particularly, growth of highways, the solutions to urban transportation have become extremely complex. Instead of only building new facilities, it is now necessary to coordinate different modes.

Planning of transportation is defined at four levels: individual facilities, single mode networks, intermodal systems and city-transportation relationships. It is shown that the latter two levels have not been adequately performed. Coordination of systems must be given greater attention. A brief review of successes and failures in urban transportation in different countries, with particular emphasis on Japan, is given at the end. The transportation and civil engineers' roles should change to include a much greater emphasis on systems approach in planning, design, operation and policy. It is particularly important that engineers give attention to the methods for achieving efficient and attractive cities.

CITIES - CENTERS OF CIVILIZATION

Cities have always been centers and symbols of human civilization. As societies and nations developed from the Ancient Times to the present, their cities represented focal points for economic, social, cultural and governmental activities.

Different forms and characters of cities depend on geography, social conditions, economy and technology; however, more than any other elements, buildings and infrastructure of cities reflect the characteristics and conditions of the countries and societies that have created them. Ancient Athens was symbolized by its Acropolis, Paris by its Eiffel Tower, Kyoto by its Imperial Palace, and New York by its skyscrapers; they all reflected their own times, their countries, and achievements of their peoples.

Analyzing cities, one can easily notice that the physical form, monumental buildings, bridges, public spaces and, particularly, their transportation systems infrastructure were created mostly by civil engineers. Thus, civil engineers have played a key role in the development of cities throughout history.

[1] UPS Foundation Professor of Transportation, Department of Systems Engineering, University of Pennsylvania, Philadelphia, PA 19104-6315, USA.

THE VITAL ROLE OF TRANSPORTATION FOR CITIES

Transportation represents one of the most important elements in forming, shaping, and functioning of cities. Locations of most cities were determined by transportation activities - ocean ports, harbors, rivers, and intersections of trading roads initiated most human settlements. When transportation systems capacities and speeds were limited by animal traction capabilities, they prevented cities from growing and expanding. As the capacities and speeds increased, urban growth was stimulated.

Consequently, available transportation technologies influenced different forms of cities: pedestrians, railways, transit and automobiles have each had a different impact on cities' densities, form, environment, and social life. Representing the lifeblood of the urban organism, transportation is crucial for its functioning, or it may represent an obstacle when it is inefficient or congested and cannot adequately serve the organism's needs.

During the period of major innovations in transportation technology and rapid growth of cities, which began with the Industrial Revolution in the 19th Century, civil engineers were the proud leaders of civic progress, improved living conditions and urban environment. They worked with enthusiasm and had the most direct involvement in providing public facilities among all engineers. Railroad networks, transit systems, highways, bridges and airports were developed mostly by the civil engineers.

THE PRESENT CONDITIONS OF URBAN TRANSPORTATION

After all these technical innovations, large investments and intensive construction of transportation facilities, one would expect that we now have efficient transportation systems serving attractive, livable cities. The fact is that transportation is the key element in our fast lifestyle, and it allows a much greater choice of living locations than was available ever before. However, vehicular traffic also presents serious problems to the urban environment and to the quality of urban life and society.

The present overall condition of many cities, and specifically, of their transportation systems, is actually far from satisfactory. In many countries urban problems are so serious, that they affect their entire economies and social conditions. Several examples illustrate some aspects of the serious problems cities are facing today.

- Millions of people spend hours every day sitting in their cars in congested traffic. This is the case in Rome, which is flooded by automobile traffic for which it was not designed, but it does not have an adequate transit system. It is also the case in Detroit and Houston, cities which have been designed for maximum use of the automobile, but such a transportation system is inefficient in large cities with multimillion populations.

- Residents of Lima/Peru, Lagos/Nigeria, Bangkok/Thailand and many other large cities in the developing countries around the world walk or travel in crowded minibuses through congested streets for 1-2 hours to come to work exhausted. To aggravate the problem, these are the fastest growing cities at the present time.

- Children in the schools of Los Angeles are sometimes told not to run on that day because the air is too polluted to breathe! Inhabitants of Mexico, Cairo, Manila and many other cities face similar problems. Most of the air pollution is produced by their transportation systems - highway vehicles.

- Most cities in the United States suffer from economic depression, poverty and crime, because large portions of their population, particularly the higher-income groups, as well as many businesses, have moved to the suburbs. One of the reasons for this trend is that suburban areas are in different towns, in which they pay lower taxes and avoid other social responsibilities of the region they live in. The transportation system, which in the United States strongly favors the private automobile over public transport, greatly contributes to the dispersal of cities and sharpening of the social segregation and economic problems.

These few examples show that most cities, in developing and developed countries, have serious transportation problems. The economic, social and environmental problems have been recognized for some time; now, increasing attention is given to the **deteriorating quality of life in urban areas**.

In an overview, one can observe that cities in developing countries suffer from insufficient transportation capacity: public transport buses and trains in Karachi, Bombay and Cairo are heavily overloaded. In developed countries, however, the problem is excessive, underutilized capacity: most cars on highways have five seats, but carry only one person; transit vehicles are filled during the peaks, but underutilized during other time periods.

Thus, with a great diversity of transportation technology and systems available, and after large investments in transportation have been made, many cities are in some ways in a more difficult situation than they were several decades ago. What went wrong?

CAUSES OF THE TRANSPORTATION PROBLEMS

In the beginning of the development of mechanized transport systems, i.e., railways between the 1830s and 1900, and then electric streetcars from 1880s through 1920s, the main problem was to find the necessary investment funds and construct the transport systems. However, already in those times, it was necessary to carefully plan entire **systems**, or, coordinated networks of lines. Moreover, the most successful cities were designed when transportation networks and terminals were coordinated with urban form, land uses and densities.

This coordinated planning of transportation and urban development required cooperation of different agencies and a unified administrative control over entire urban areas. Where these conditions existed, this period of railway and transit development resulted in construction of efficient and attractive cities with strong, economically sound central areas and subcenters located along major rail transit lines. Such urban forms remain crucial for urban functioning even today.

Invention of additional transportation systems, such as bicycles, buses and, particularly, the private automobile, new opportunities for urban development appeared. The highway transportation system provided virtually ubiquitous transportation and increased the distance which people could travel. The opportunities for different types of transportation and for spreading of cities and metropolitan areas increased. However, the complexity of transportation systems also greatly increased and much more comprehensive planning and coordination of different activities became necessary.

This new complexity of transportation systems and the need to analyze their impacts on cities was not understood in many cities and countries. Thus, during the 1950s and 1960s, most large metropolitan areas in the United States, as well as in Great Britain and some other countries, performed "comprehensive long-range transportation planning studies". However, these studies did not have clearly defined **goals for transportation systems and for cities**. They tended to provide maximum **vehicular** mobility, not realizing that such mobility may have serious negative side effects on urban environment and quality of life.

An even greater problem was that this planning 30-40 years ago was based on the belief that the private automobile will be by far the most important, basic mode of transportation even in very large cities, such as Los Angeles, Detroit and Houston. Even the well-publicized studies in Great Britain, such as the one by Buchanan and theoretical studies by Smeed, failed to realize that **large cities must rely on multimodal systems**. To achieve such a system, a **high quality transit system must be developed and use of the automobile must be discouraged** to keep a reasonable balance among different modes. This is true not only for auto and transit, but also for pedestrian traffic, which is a basic element of livable cities.

Thus, while these studies utilized the capabilities of newly invented computers to handle and analyze large amounts of data, they represented a conceptually deficient effort which often led to undesirable developments in cities which are now very difficult to correct. Actually, the cities which rushed to quickly build the extensive freeway networks, while neglecting transit, now have much more serious transportation and urban problems than cities which were slow in construction and had a chance to reevaluate their plans.

For example, Los Angeles had 700 km of freeways in mid-1960s; the transportation plan proposed an ultimate freeway network of over 2,500 km, but there was no concrete plan for any high-quality transit network. Freeway construction has now stopped after 1,750 km were built and major efforts are being made to develop rail transit (light rail, metro and commuter rail), but this is very difficult in a city which grew with total reliance on freeways. On the other hand, the plans containing similar extensive freeway networks which were not built immediately, such as those for Philadelphia, San Francisco and London, have been extensively reduced, or completely abandoned.

Consequently, planning and construction of individual facilities, such as highways, parking garages or subway lines, has been much more successful than planning of complex transportation systems, particularly when they consist of several different modes.

It took considerable time for transportation planners to realize that impacts of transportation facilities and systems on entire regions and on the quality of life in them must be included in planning; actually, these impacts are sometimes more important than the direct costs and benefits of individual infrastructure objects, such as freeways or subway lines.

It is useful to compare transportation planning, controls and regulation procedures with the procedures used in other urban systems.

Suppose that in a 40-story apartment building constructed in Hong Kong during the 1970s several apartment owners have become more affluent and they want to put large bath tubs and jacuzzis in their apartments. They would have to apply for permission and probably not be allowed to introduce such "innovations". The reason is that if they were allowed to build such bathroom facilities, the residents on upper floors would often stay without water. Moreover, the building may not be structurally fit for such changes. Neither the water supply nor the structural design had been designed for the greatly increased water consumption and loads. Thus, the control is necessary and quite logical.

Yet, in many cities construction of large buildings and other developments are permitted without checking whether the highway system can serve them, whether there is a good transit service, whether pedestrians can get to the site, etc. Thus, in transportation we often allow unplanned, uncoordinated development that leads to congestion, inadequate transit services and, eventually, deterioration of entire urban areas.

There are other paradoxes in transportation, which we do not tolerate in other systems. For example, it is common in most systems to favor large over small vehicles: large ships have preference over small boats; a Boeing 747 Jumbo jet is favored over a small propeller plane, etc. Yet, in urban transportation our policies and traffic controls give the same rights to an automobile carrying one person as to a bus carrying 50 persons. We still behave as if we want to transport as many vehicles as possible, rather than as many persons as possible - a paradoxical and illogical practice.

These examples show a clear tendency to treat transportation at a rather primitive level, considering mostly its individual facilities, its short-term problems and requirements, rather than long-range impacts of the entire transportation system.

ANALYZING URBAN TRANSPORTATION AS A SYSTEM

To better understand the complex problems of urban transportation and evaluate which aspects are performed well, and where the problems are, it is necessary to utilize a systems approach.

Planning, organization and operation of urban transportation can be classified by its objects, scope and domain in four levels, from the simplest individual elements to the overall city/transportation systems level. The four levels, shown in Figure 1, will be defined here, and characteristics of each one will be briefly discussed.

Level IV: Individual Facilities. The lowest level represents individual transportation facilities, such as an arterial street, major intersection, a freeway, a bus or metro line, or a pedestrian plaza.

The planning, design, construction and operation of these facilities is done, generally, quite well. Although the design engineer must consider not only structural aspects of the facility, but also its operation, control, etc., the organization, financing and operation are usually under direct control of a single agency - the highway department, City's department of transportation, or the transit agency.

Level III: Single Mode Networks. A network of any one transportation mode represents a higher level system than its elements - individual facilities. It is, naturally, more complex because it involves interactions of many different components and its operation allows many more factors and variations than operation of individual facilities. Examples of networks may be a network of bicycle paths (common in many European countries), street network in central city or in a residential area, a network of bus lines, or of regional rail lines in a metropolitan area.

In general, networks are also usually well designed when design teams have engineering expertise. Ideally, a transportation engineer develops functional design, considering various planning requirements and constraints, civil, mechanical and electrical engineering elements, system operations, its economic efficiency, and other factors. A structural civil engineer is usually the leading person in the construction of the network infrastructure.

Jurisdiction and funding are also usually unified under one agency, facilitating the system approach and coordination of activities.

The problems in network design have occurred when the required expertise is not available, or when such factors as unstable financing, policy changes or political interests change in the course of network construction. Since network construction usually takes many years, such changes are not rare.

Level II: Multimodal Coordinated Systems. This is the highest level system of transportation in a city or metropolitan area: it incorporates all modes, including highways (auto, bus and truck), rail and other transit, as well as systems of pedestrian and bicycle facilities, and other transportation "subsystems".

This level, dealing with the entire transportation system, is much more complex than the preceding ones for several reasons:

- The system performs a much more complex function than individual modes;
- To be efficient and provide good service, this system must integrate modes so that they complement each other, which is often a complex task;
- Multimodal system supersedes single mode jurisdictions. It therefore requires intermodal agencies, which most metropolitan areas do not have.
- Financing from different sources and different methods of revenue collection represent additional problems in coordination and integration;
- Narrow interests and often **different mentalities of agencies and experts in charge of different modes of transportation** often represent a major obstacle to cooperation at this level.

The preceding text has shown that with the development of different transportation technologies

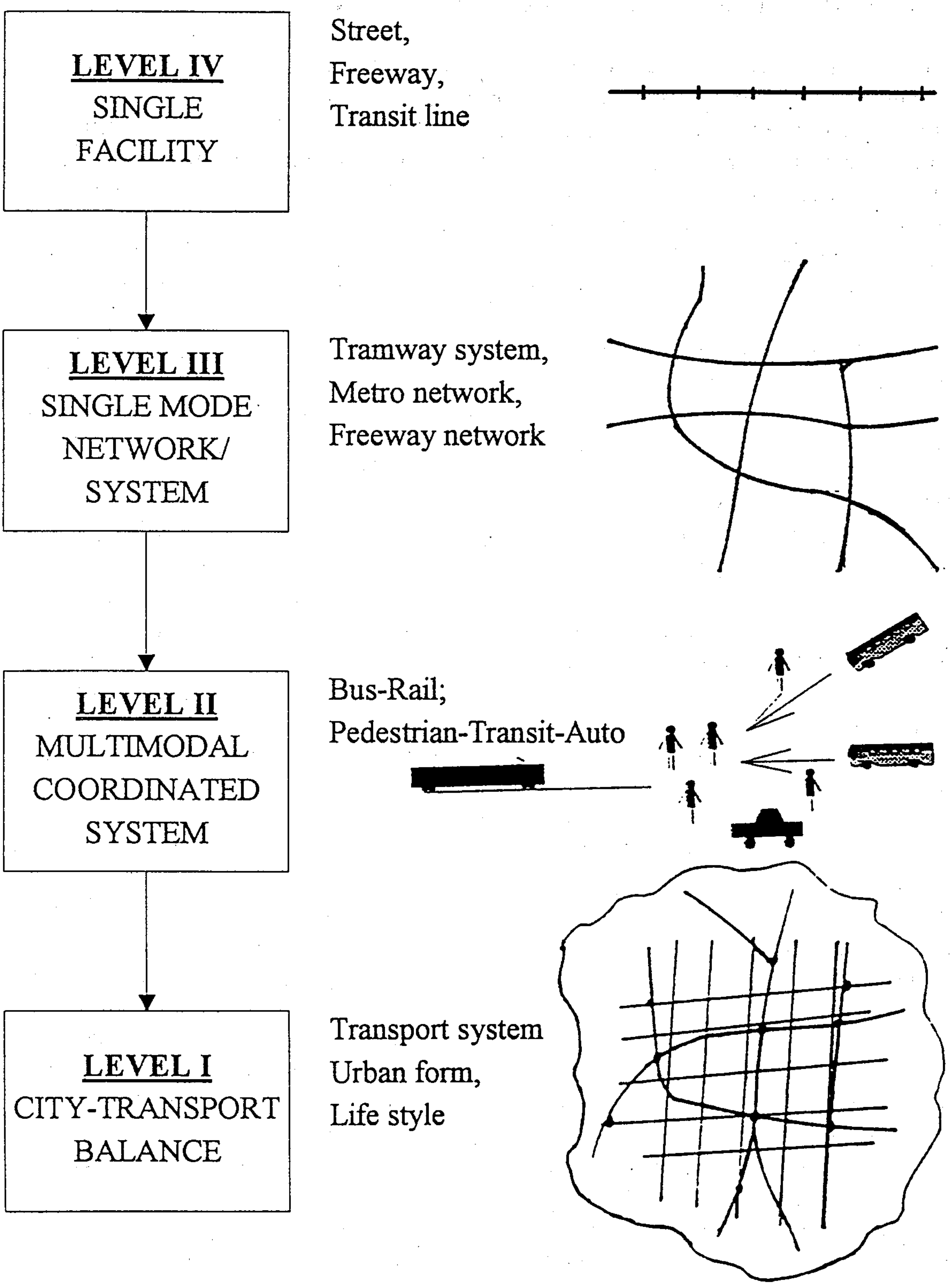


Fig. 1 Conceptual classification of urban transport planning

during the last 150 years, the importance of system planning and integration at this Level II has become increasingly important. However, the understanding of this system and methods of its integration have been lagging behind the developments of lower level transportation components; it has also lagged behind the understanding and policy levels in many other sectors, such as building codes or coordination of various utilities. In the last section of this paper it will be shown that Level II integration has been rather successfully implemented only in a few countries.

Level I: City-Transport Relationship. Coordination between the transportation system and the city - its physical components and form, economy, social life and environment - represents the highest level of planning and operational integration.

This coordination is by far the most important of all four levels, because an efficient and attractive city is certainly the highest goal toward which transportation planning and services should lead. However, Level I planning is most complex both theoretically and practically, and it is a process which is in most cities done at a rudimentary level only.

The main reason for the failures in this level is not only the complexity of planning and involvement of the different agencies and jurisdictions, but quite limited understanding of the impacts of different modes of transportation on the city's form and on the entire quality of life and ultimately, type of society which is created in cities.

The most serious error in planning during the 1950-1970 period were made in this area: the **goals for cities in terms of the quality of urban form, character and quality of life were not clearly defined**. In some studies which defined them, there was no full recognition of the fact that **to achieve an efficient and attractive environment, large cities must have multimodal transportation systems.**

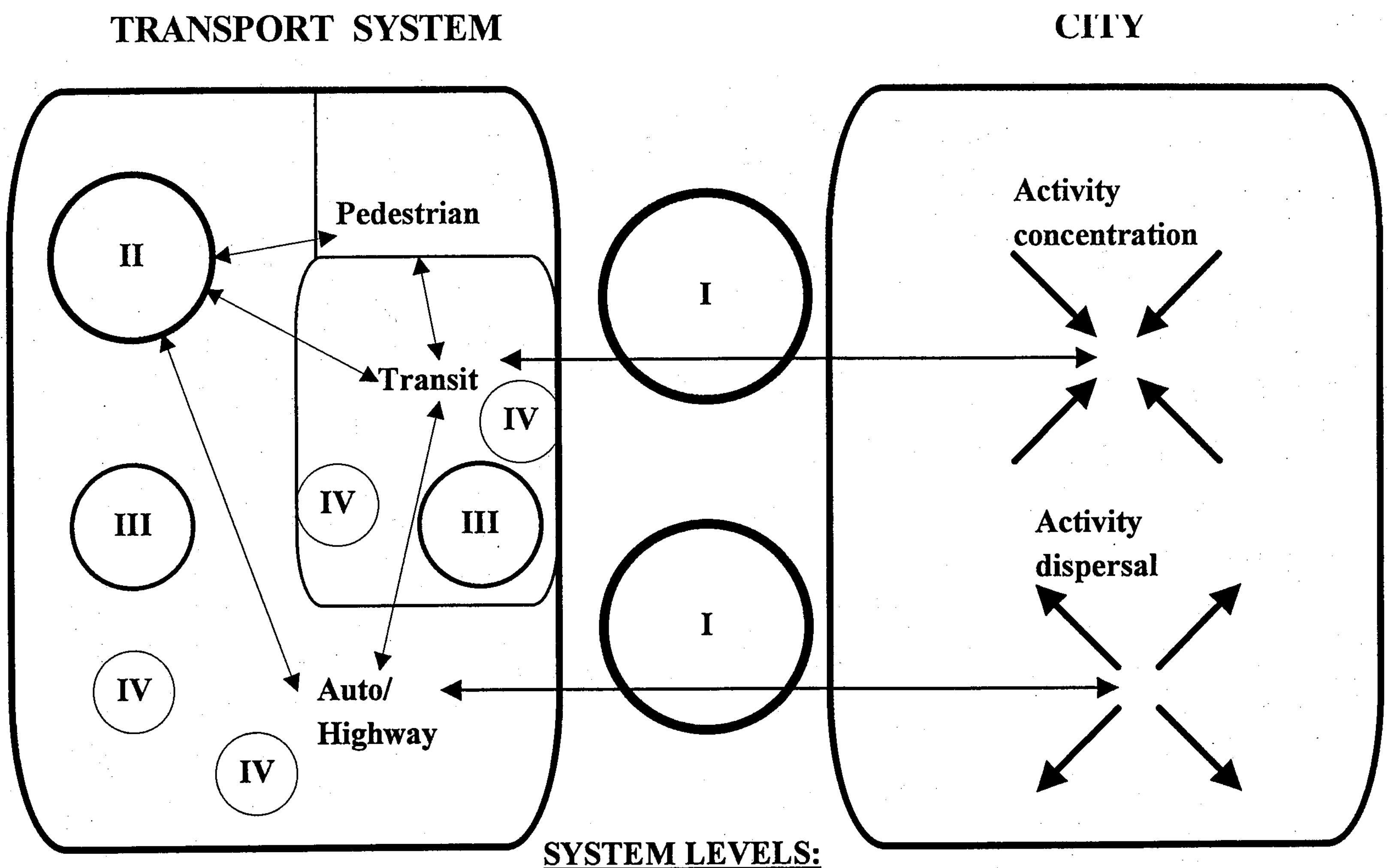
Without the city/transportation (Level I) coordination, cities can seldom achieve high levels of efficiency and livability.

Figure 2 shows schematically the four levels of urban transport systems planning. Their domains, scopes and relationships are graphically depicted, showing the dominant role of the Level I. The arrows at this level show that in the city transit systems tend to develop focal points, while the automobile generally tends to disperse activities.

These definitions and understanding of the levels are very important to prevent confusion. For example, the politically-instigated push for deregulation of bus transit in British cities was based on the claim that the main problem in urban transportation were high subsidies to transit. The fact that, with the exception of London, transit in Great Britain had been neglected and virtually no capital investments given to it for the preceding 40 years was not mentioned.

Consequently, high transit subsidies in Great Britain were the result of distorted policies which favored private over public transportation. The report "Buses", which argued for deregulation, thus claimed that inefficiency of transit systems (Level III) was the main problem; actually, this problem was caused by the long tradition of transport policy errors (Level II), which had major negative consequences on the city/transportation system relationship (Level I). The deregulation promoters did not even discuss these highest level problems.

The definitions of the four levels of planning allow better understanding of the **sequence of planning in urban transportation**. Due to the complexities of the higher levels, there is a tendency to plan only at the facilities and single mode levels (IV and III). Actually, if the goal is to achieve an efficient and attractive city, the sequence should be as shown in Figure 3: it should start from Level I, determining what type of city and society should be achieved; that then determines the composition or "balance" of modes (Level II). After the roles of different modes are determined, the guidelines are prepared and planning of networks and facilities of individual modes (Levels III and IV) can be performed.



SYSTEM LEVELS:

I - Individual facilities
II - Single mode system
III - Multimodal transport system
IV - City/transport interactive system

Fig. 2 Schematic presentation of urban transport planning levels

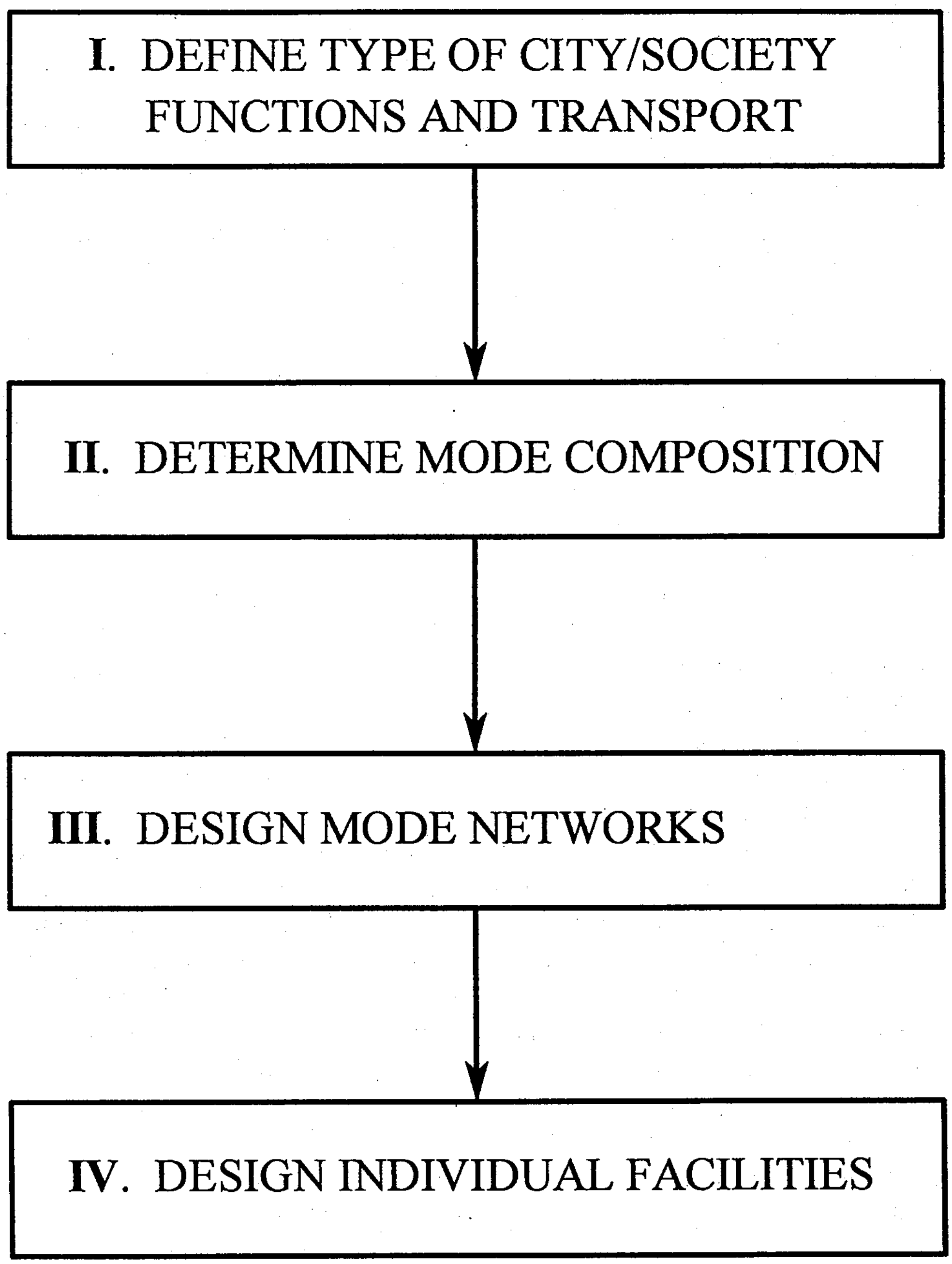


Fig. 3 Planning sequence in urban transport

SYSTEM ASPECTS TO BE SOLVED

Once the desirable intermodal balance is defined, the problem is how to implement and maintain it. This **maintenance of an intermodal balance represents the focal transportation problem in many cities.** The policies and methods used to achieve and maintain a desirable balance vary greatly among cities and countries.

The fundamental problems in achieving and maintaining a desirable balance among modes, as well as within individual modes, are described and discussed here.

Problem I: Individual vs. Social Interest. The trade-off between individual and social interests (local and global optimum) exists in many areas of a civilized society. Immediate personal convenience often leads to major social problems. Therefore, the society must limit certain actions of individuals (which are sometimes misnomered as "individual freedoms") in order to avoid long-range problems or malfunctioning of entire systems, from which each individual would ultimately also suffer. For example, penalties are used to prevent throwing of trash in public places. Legal regulation is used to force auto drivers to keep exhausts from their automobiles below certain levels. Parking is prohibited in many streets to maintain better traffic flow. Pricing is sometimes used to reduce peak hour demand for public events, to spread the loads on telephone lines, etc.

Shifting automobile traffic between two (or several) alternate highways is sometimes done to optimize network operation. Some of the travelers then experience an increase of travel time, but total travel time on both alternative routes is decreased.

The major problem in cities, balancing the travel volume between auto and transit, is illustrated in Figure 4. The diagram shows costs of travel in an area for a total number of trips P, which are distributed between auto (Pa') and transit (Pt'). Unit travel cost by automobile (Ca'), plotted from the left, increases with travel volume due to congestion. Unit cost of travel by transit (Ct'), plotted from the right, decreases with increasing travel volume because transit service is more economical and more frequent when passenger volume increases.

If a portion of auto users ΔP would switch to transit, lower volume of auto traffic would reduce average costs to all auto users, while increased transit ridership would make a better transit service economically viable. Thus, as the diagram shows, a shift of the intermodal division line from I to some point S' would benefit both groups of travelers. The problem is, however, that at the point S' the situation is not stable: some transit users would notice that auto travel is less costly and they would switch back to automobiles, until the division returns to point I. To achieve a stable socially desirable balance, public policies and actions should create conditions which would bring the intermodal division by users' choice to the left of I: S should become a stable division point. This shift of travel can be achieved by two different policies:

Policy I: Make transit more attractive (lower the Ct' curve to Ct); and,

Policy II: Make auto travel less attractive (raise the Ca' curve to Ca).

Actually, the diagram shows that a combination of these two policies is the most efficient way of shifting the intermodal division of travel from the individual optimum (I) to the social optimum (S).

The policies I and II, popularly known as, respectively, **Transit Incentives** and **Auto Disincentives**, can be implemented by many different measures, including infrastructure construction (e.g., a new light rail transit line), regulations (such as traffic flow controls) and pricing (subsidized fares, increased parking charges).

This analysis leads to another major problem: structure of costs and charges for auto and transit travel in cities. As Figure 5 shows, cost structure for auto is very different from that for transit. The diagram illustrates the following important facts:

a. Total (user and social) costs of auto travel are much greater in cities than in rural areas;

b. Operating costs of auto travel are much smaller than fixed costs, particularly if parking is free or subsidized;

c. In cities there are substantial social (congestion) and environmental(air pollution, urban

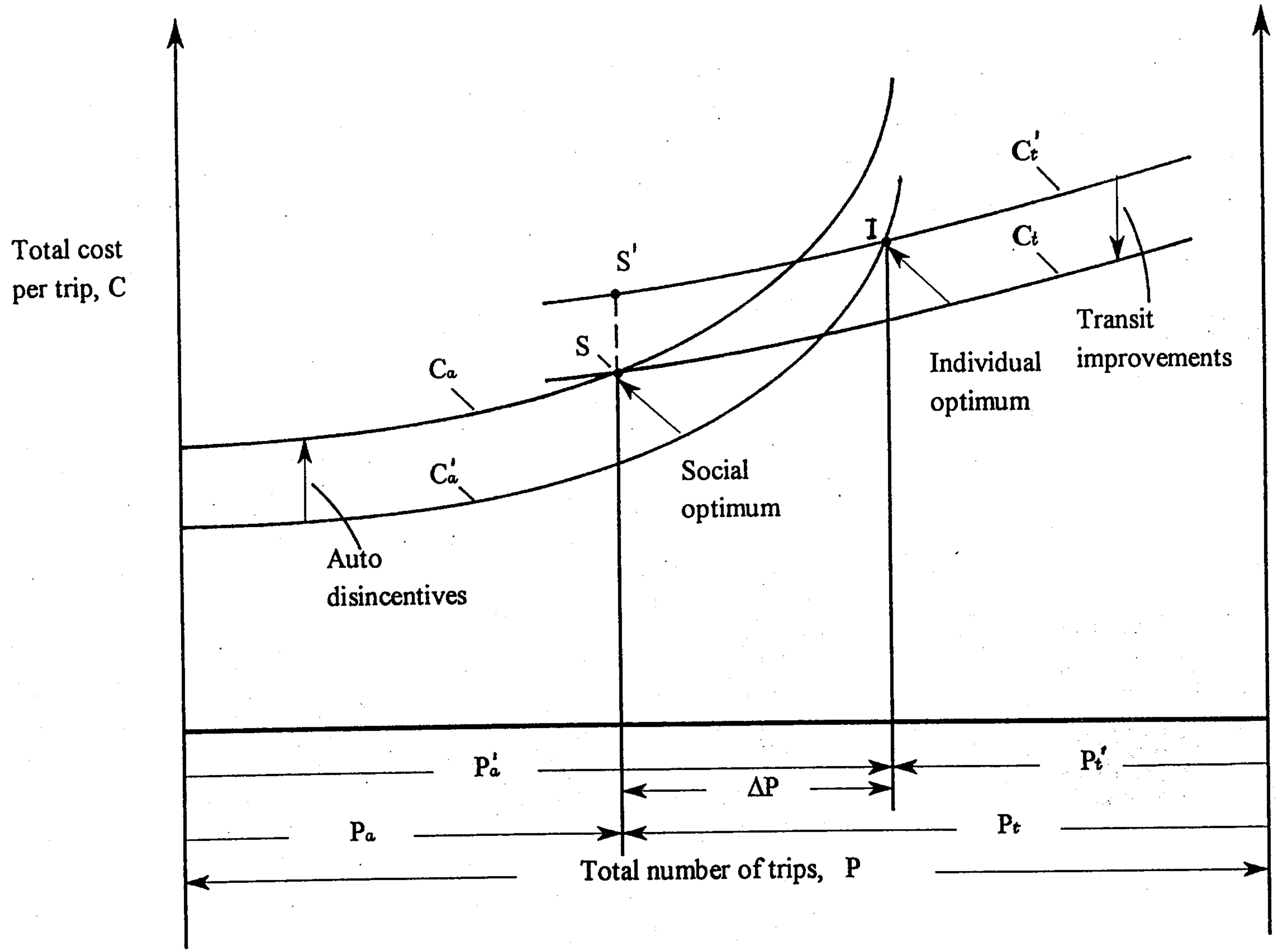


Fig. 4 Travel distribution between auto and transit

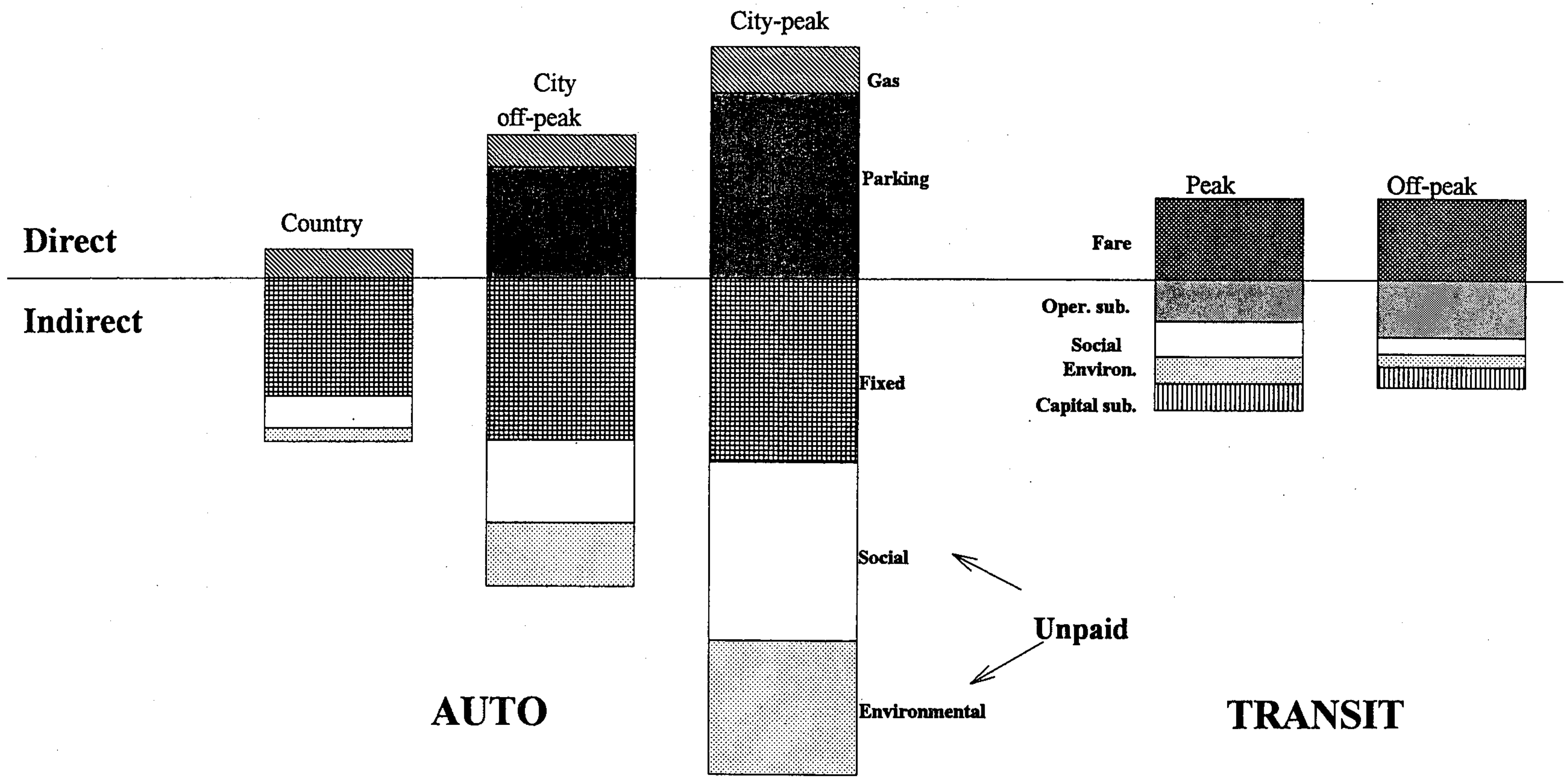


Fig. 5 Structure of travel costs by different modes

sprawl) costs which auto users do not pay;

d. Since most urban travelers choose mode of travel on the basis of direct - visible costs only, transit fares must be kept low to keep transit travel competitive.

These facts lead to the following major conclusion:

The main reason for transit subsidies is the structure of costs of auto travel, namely the facts that auto travel is subsidized, most of the costs are fixed (unrelated to individual trips) and social costs are not charged for at all.

Increasing the direct costs of driving automobiles in cities is therefore a very effective method of influencing division of travel between auto and transit. It not only discourages auto use, but it also reduces the need for excessive transit subsidies. Methods of increasing these costs include higher taxes on gasoline and shifting of auto insurance from fixed charges to an addition to gasoline price. However, parking charges, entrance fees to central urban areas and road pricing represent by far the most effective forms of direct cost increases.

AN INTERNATIONAL REVIEW OF ACHIEVEMENTS IN URBAN TRANSPORTATION

There are major differences among the policies and actions concerning urban transportation in different countries. While some countries are rather advanced and have introduced many innovations in creating healthy and attractive urban areas, others continuously face a major urban crisis and have little success in dealing with that problem. A brief international review is therefore interesting and useful. There is much to be learned from the successes as well as from the failures of urban transportation policies and actions that occurred in recent decades.

The United States made great progress in urban transportation during the 1970s: the importance of multimodal systems for urban revitalization was recognized and a major effort to improve transit, pedestrian areas, and "livability" of cities was undertaken. During the 1980s there was, however, a retrogress toward highway-dominated solutions, and the urban crisis sharpened. Polarization of economic and social classes increased greatly, leading to an intensified "flight" from cities to suburbs.

The current federal transportation law (known as ISTEA) as well as the "Clean Air Act", adopted in the early 1990s, are very progressive: they explicitly require a greater emphasis on integration of modes and discouragement of single-occupancy vehicles, particularly in cities. The problem is, however, a strong pressure of habits and of different lobbies interested in further continuation of the heavy reliance on the private automobile only.

Consequently, the positive requirements of the existing laws have only a limited success due to the strong pressures against their implementation. For example, the **heavily financed IVHS (Intelligent Vehicle Highway System) program, used in Europe as a means to better coordinate different modes, is seen by most of its promoters in the United States as a chance to increase vehicular capacity of urban highway systems - a goal directly contrary to the mentioned federal laws.** The program's name, IVHS, by itself indicates its one-sided orientation. The title should be ITS - Intelligent Transport System - because it is not limited to highways only.

The main problem in US cities remains a lack of clear definition of the goals for cities - the Level I decision. Under confused guidelines, many present activities are continuing the developments of land uses without any relationship to the present and planned transportation systems.

Japan has an interesting set of achievements and problems in urban transportation. In some respects, this country is extremely advanced; in others, it lags behind other industrialized countries.

In transportation technology (Levels IV and III), including rapid transit, regional and long-distance railways, Japan is definitely among the world leaders. Its highway and freeway systems have been rapidly developed despite geographic difficulties, although traffic congestion is still a major problem. Traffic engineering is good, and safety has been greatly improved in recent years. Many attractive pedestrian areas have been built in Japanese cities. Urban planners and transportation experts give serious attention to urban environment and livability of cities.

With respect to intermodal integration, Japan has a somewhat mixed record. In these activities, defined above as Level II, there are some remarkable achievements: the integration of different rail systems, such as TEITO, JR and private railways in Tokyo, is very well organized and successful. However, integration of rail systems with buses is inadequate, and in many cities even internal integration of bus systems is rather poor.

Several other aspects of urban transportation in Japan which need improvements include the following ones at Level III:

- Planning and construction of AGT (Automated Guided Transit, also known as People Movers) is carried separately from the planning of rail transit systems. The fact that AGT vehicles run on concrete guideways places this transit mode under the Ministry of Construction, while guided modes which run on steel rails are under jurisdiction of the Ministry of Transport! This organizational setup is historical, rather than functional, and it represents a major obstacle to integrated transit planning;
- Highway and street systems operations are not fully integrated either. Their design, operation of signals and enforcement of regulations are performed by different agencies, such as Police, municipal and prefectural departments.

Several examples indicate failures at Levels II and I of urban transportation planning:

- Coordination at Level II - between transit systems and highways - is inadequate; actually, it is difficult to achieve it when there are major problems in coordination at Level III.
- Similar to the United States, research and development under the IVHS program is given very high expectations, but definition of its goals is not quite clear.
- At Level I, there are no single, unified metropolitan transportation agencies which develop and implement a coordinated transportation/land use systems. Yet, a number of Japanese cities have built many urban subcenters fully integrated with major transit, auto, bicycle and pedestrian facilities. Examples of urban developments well integrated with transportation systems are the Shinjuku complex in Tokyo, shopping centers at main railroad stations in many cities, and suburban commercial and residential communities developed by private railway companies (for example, Odakyu, Keio, Tokyu) that are focused on multimodal transit centers and pedestrian areas.

This very brief review indicates that, in general, Japanese engineers have an outstanding record in designing and construction of facilities and individual systems (Level IV), but improvements are needed in integrating and coordinating transportation systems, particularly at Levels III and II.

West European Countries have a very diverse record in urban transportation. On one extreme, some cities in Southern Italy and France have rather chaotic traffic conditions and few activities to improve quality of urban living. On the other extreme are most cities in Germany, Switzerland, Scandinavia, Benelux, as well as some in Austria, France and Spain, which are the most advanced in understanding the complexity of urban transportation and in the basic policies required to develop efficient and livable cities.

The advanced transportation features found in the most developed European cities include the following ones.

- Considerable investments have been made in construction of modern infrastructure for all modes, from pedestrians to freeways and regional rail systems;
- High-quality street/highway design and traffic engineering, giving full attention to auto, bus, light rail, bicycle and pedestrian modes;
- Transit systems which are fully integrated functionally, physically and operationally (e.g., Hamburg, Munich, Zürich);

- Policies aimed at achieving a desired balanced between auto and transit modes; implementation of these policies utilizes a set of transit incentive/auto disincentive measures;
- Great attention given to the human-oriented urban environment, both in urban centers and in residential areas;
- Coordination between urban development and transportation is very good in many cases (Sweden, some German and Dutch cities). Yet, there is not sufficient control of developments in suburban areas. What prevents the excessive sprawl typical for U.S. cities is that central cities are kept healthy and attractive, so that they successfully compete with suburbs.

In conclusion, many European cities have been very successful in solving problems at Levels IV, III and II; a few have had successes at Level I also.

Great Britain is in many ways a special case, lagging far behind other West European countries in urban transportation. While British theoreticians have pioneered many theoretical studies (Wardrop, Smeed, reports of the Transportation Research Laboratory), actual policies and their implementation in that country are far behind those in other countries. Much of the theoretical thought is dominated by economists who divert attention from actual physical systems to their short term financial results.

Due to this narrow focus on business aspects of transportation (competition, market principles, etc.), the British government has in the last 14 years badly neglected the **public interest** and **long term goal of achieving efficient and livable cities**. For example, British laws now prohibit existence of multimodal agencies: companies operating rail transit cannot operate buses! Consequently, Level II coordination is prevented by law; deregulation has also severely damaged activities at Level III, while the work at Level I is pursued only in theoretical circles.

Among successful activities in urban transportation, one must mention two other countries. **Canada** has by far the best urban transportation planning and implementation in North America, including the coordination at Level I. **Singapore** was in 1975 the first city in the world to implement a complete intermodal coordination utilizing auto use pricing to control traffic flow on center city streets, as well as to influence the balance between modes (Levels III and II, respectively). It has also been successful at Level I, coordinating urban development and transportation.

ENGINEERS' ROLES IN URBAN TRANSPORTATION

The field of transportation has always been a major domain of work for many engineering professions, particularly for civil, mechanical and electrical engineers. Already at the early stages of mechanized transportation systems, some 100 years ago, complexity of transportation systems led to an early cooperation among different professionals and formation of interdisciplinary teams. Unlike many other engineering fields where physical items are produced and given out for use, transportation involves engineers not only in design and construction, but also in continuous system operation.

Urban transportation differs from other transportation fields by its character in several ways. First, intermodal systems are more complex than individual modes. Second, because of their major impacts on cities, economy, environment and society in general, urban transportation has a much more public nature and involves more influences than most other engineering fields and tasks.

Due to these characteristics, urban transportation requires sophisticated and comprehensive understanding not only of transportation systems, but also of cities and interactions between the two. **These complex interactions between cities and transportation represent a special challenge for engineers**. They require stronger interdisciplinary cooperation and full understanding who the "clients" are. The civil engineers often have the leading role in working for and protecting the public interest. When alternative solutions are developed and evaluated, implementation must follow. Therefore, policy, organization and financing issues must also be resolved.

There is no doubt that transportation will remain a major area of involvement for civil, mechanical, electrical and electronic engineers. Applications of communications and computers will continue to grow. However, if engineers are to maintain, or in some cases regain, the leading role in transportation systems planning and operation, they must broaden their knowledge and expertise.

Increased complexity of the society, greater technological choices, consumer desires and political relationships require engineers - civil more than any others - to understand the **systems**. That includes not only technical systems, but relationships of technical systems to the economy, society and environment.

Better organization of transportation systems and their coordination with other urban functions thus represent the main challenge engineers are facing today. The preceding examples of the complex transport problems show that they can be solved only through the use of **SYSTEMS APPROACH** to urban transportation.

Consequently, in addition to their traditional expertise in construction of infrastructure and other facilities, civil engineers involved in urban transportation must broaden their expertise to systems approach in analysis of urban transportation. That is a major challenge our heavily urbanized society faces today.

REFERENCES

Cisneros, H. (Ed.) (1993): Interwoven Destinies: Cities and the Nation, W. W. Norton & Co., New York.

Hans-Klau, C. (Ed.) (1988): New Life for City Centers: Planning, Transport and Conservation in British and German Cities, Anglo-German Foundation, London.

Homburger, W. S. and Vuchic, V. R.(1972): Transit Federation - a Solution for Service Integration, UITP Revue - Vol. 21- 2, pp. 84-91. UITP, Brussels.

Newman, P. et al. (1992): Winning Back the Cities, Australian Consumers Association, Pluto Press, Australia.

Pucher, J. (1988): Urban Travel Behavior as the Outcome of Public Policy:the Example of Modal-Split in Western Europe and North America, Journal of the Amer. Plan. Assoc. 54/4, Autumn 1988, pp. 509-552.

Pushkarev, B. and Zupan, J. (1977): Public Transportation and Land Use Policy, Indiana University Press, Bloomington, IN.

Thomson, M. J. (1977): Great Cities and Their Traffic, Penguin Books Ltd.

Vuchic, V. R. (1986): Deregulation: a return to the primitive, City Transport, May/July.

Vuchic, V. R. (1981): Urban Public Transportation Systems and Technology, Prentice-Hall, Englewood Cliffs, NJ.