TRANSPORT SYSTEMS AND POLICIES FOR SUSTAINABLE CITIES

by

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The 20th century witnessed revolutionary developments in transportation technology with major impacts on the form and character of cities. Progress in increasing mobility has brought many benefits as well as serious problems, particularly in deterioration of livability and sustainability.
Increase in auto ownership led to serious problems of chronic traffic congestion. Attempts to rebuild cities to provide full accommodation of private cars have led to serious problems of auto dependency and deterioration of cities. Experiences from recent decades have shown that urban transportation is much more complex than usually realized. Livable and sustainable cities require policies that lead to creation of a transportation system consisting of coordinated public transit and private cars, and encourages pedestrian environment and efficient, sustainable development. Great need for better understanding of the complex problems in implementing incentives and disincentives aimed at achieving intermodal balance is emphasized. Brief descriptions of cities which lead in achieving such livable conditions is followed by a summary of lessons and guidelines for the future.

Key words: *urban transportation systems, intermodal balance, individual equilibrium vs. social optimum, livability and sustainability of cities, urban transportation policies*

Our heavily urbanized civilization strongly depends on the health of cities. Transportation, the focal subject of this article, is a major contributor to the economic, social, and environmental conditions in urban areas, *i. e*., the quality of life which their residents and visitors experience. Transportation is interrelated with other service and supply systems, such as energy, water, and environmental conditions, so that all these systems are essential for operation of cities and for their present livability and projected sustainability.

Present condition of urban transportation: progress and problems

Transportation efficiency and travel conditions vary greatly among countries, local conditions, sizes of cities, *etc*. Yet, it can be said that today in most cities transportation provides a very high degree of population mobility: large volumes of people travel greater distances than ever before. This mobility provides great economic and lifestyle benefits. However, transportation in many cities continues to have also serious deficiencies and, in many cases, results in problems that are increasing with time and therefore do not satisfy the growing requirements for sustainability.

To illustrate the preceding statements, in many large cities millions of their residents can travel throughout their urban areas by trains or cars at speeds of 50 or 100 km/h with good safety and comfort. However, most large cities also suffer from serious deficiencies of their transportation systems, as well as from negative impacts these systems have on their users as well as on the entire urban population. Many of these system inefficiencies (low reliability due to congestion, traffic accidents) and general impacts or "externalities" (negative impacts of congestion, large parking garages, noise, *etc*. on urban environment) affect sustainability of cities and therefore require particular attention here.

Transportation system users – urban travelers – often face the following inadequacies in the services they obtain:

- unreliable services which cause uncertainties in travel and require longer time allocations,
- low service quality and time losses due to street and highway congestion,
- accidents causing deaths, injuries and damages which are globally estimated to be more than twice greater than quantified user losses due to congestion,
- inadequate transit services which stimulate people to use cars, thus aggravating traffic congestion, and
- walking and using bicycles are sometimes neglected and made unpleasant by heavy vehicular traffic.

In addition to user problems, most large cities suffer from negative impacts of transportation on the entire urban area, its life style and character. These system impacts include:

- chronic traffic congestion results in continuous noise and air pollution, as well as in creation of environments unfriendly to pedestrians,
- large areas and buildings dedicated to parking which disperse human activities and often lead to urban decay,
- these types of land uses and urban environment stimulate greater use of private automobiles which leads to further increases of congestion and blight, thus creating the "vicious circle of urban transportation,"
- heavy reliance on private cars causes some serious national problems, such as excessive energy consumption and oil imports resulting in many countries in major trade deficits, and
- in the long run, this condition is being increasingly recognized as a major cause of global warming and trends that prevent sustainability.

Urban transportation analysts who discussed this relationship of auto-oriented urban environment and livability of cities have named this problem the "collision of cities and cars" [1, 2].

Development of urban transportation during the 20th century

At the beginning of the 20th century, the "Industrial Revolution", started about a century earlier, was still in the full swing of development. That economic development combined with population growth and the phenomenon of urbanization – movement of population from rural to urban areas – led to a rapid growth of cities [3].

The railways, invented in 1825, provided excellent intercity transportation, but intraurban transport still consisted of walking and horse-drawn vehicles which offered low speed and capacity. Until 1890s, the cities were therefore mostly compact, "Walking Cities" [4], and in great need of faster travel. Electric tramways had just started to change and greatly improve urban travel.

With the invention of very efficient electric traction, tramways and metro (rapid transit) systems (and since the 1920s buses and trolleybuses) represented an ideal solution for provision of faster travel along urban arterials, allowing working population to move from congested central cities to more attractive residential areas. Instead of travel to work limited by walking to 2-4 kilometers, tramways and subways allowed upgrading of Walking Cities into "Transit Cities" in which people could commute 5, 10, or 15 km from the growing suburbs.

Between 1890s and 1950s industrialized countries experienced the development of transit cities with ubiquitous networks of tramway and bus lines, and in large cities also with metro and regional rail systems on separated alignments, free from street congestion, providing much greater speed and capacity along major corridors or entire networks. By the 1950, about 20 cities had metro networks.

The growing auto ownership started in the United States from the 1930s, and in other industrialized countries from the 1950s. In the U. S. this phenomenon was used by the very strong interests and political power of the highway construction, auto manufacturers and oil companies to force full orientation toward construction of streets, highways, and parking garages and neglect of all other modes, including public transportation and pedestrians.

This condition led to the creation of "Automobile Cities", most typical of which are found in the U. S., Canada, and Australia. Many cities in these countries built freeway networks across the entire urban areas, including tight rings around their central business districts. Garages in many of these cities represent more than half of the buildings in central urban areas, while pedestrian travel became much more limited than before because entire urban areas became unattractive to people.

Interestingly, although the freeway systems were built to decrease congestion, experience has shown that the cities which built the most extensive freeway networks, such as Houston, Detroit, and Los Angeles, today suffer from congestion more than the ones with limited freeway networks and strong transit systems and pedestrian orientation. The reason is rather obvious: in the long run, the Automobile Cities have such low densities that trips become much longer and vast majority of them can be only made by private cars. Thus, the auto-based cities were actually designed to maximize the need for driving and thus for maximum energy consumption. This created another "vicious circle": the more freeways were built, the more congested they became. When this unsustainable condition was created, it gradually led to the conclusion that "cities cannot be freed from traffic congestion just by building more highways". In popular terms, it has been said that attempts to solve congestion by building more highways only is similar to attempts to cure obesity by providing longer belts.

Excessive auto-dependency has had not only physical, but also social impacts [5]. In such cities persons who do not own, do not drive or do not want to use cars have actually become second-class citizens. They are seriously disadvantaged because of their much lower ability to travel to work, shopping, or social activities. Consequences of this condition have increased economic segregation and intensified problems of low-income groups in urban as well as in rural areas.

Photo 1. Collision of cities and cars: traffic congestion is a chronic problem in most cities

Photo 2. Attempts to accommodate most urban travel by car have resulted in devastating impacts in many large cities (Chicago)

Photo 3. "Auto-based cities" with huge highways and parking facilities seriously decreased their livability (Center of Los Angeles around 1965)

Experiences from recent decades

Urban transportation planners and engineers have been facing the difficult task of coping with growing cities, increasing demand for travel and changing roles of different modes – primarily transit, private cars, and walking. Very briefly described, they had to plan and implement construction of major networks of roads and parking facilities, development of traffic controls, safety, and environmental aspects.

The field of traffic engineering, founded in the U. S. in 1930, was broadened and complemented by transportation systems management – TSM, by travel demand management – TDM, by the large field of urban transportation planning, and by new technology fields such as intelligent transportation systems – ITS or telematics (European term), applied to many functions of highways as well as transit [6]. However, the seriousness of transportation problems and their interactions with cities clearly demanded broader studies of these problems that have to include not only technical and planning activities, but also economic, social and environmental aspects.

Already during the 1960s such a comprehensive study was performed in Great Britain by C. Buchanan and his report "Traffic in Towns" [7] got wide publicity. That report increased awareness of the complexity of the city-transportation relationship, but it failed to bring clear and realistic policy guidelines because it failed to understand the features which determine the choice of people between public and private transport. Thus, Buchanan suggested that when traffic congestion increases, more buses should be provided; actually, that is a simplistic view because under such conditions drivers will not leave their cars to take even slower buses.

At about the same time a "Committee of Experts" in Germany worked on the same problem and produced much more analytical definition of problems and principles of solutions. The Committee's report [8] stated that all population groups should have an acceptable mode of transportation (preventing auto dependence) and investments should be made to develop a balanced and coordinated system of private and public transport. The Committee made specific recommendations for financing such an intermodal transportation system. Those recommendations became a federal law in Germany, which is the basis for the fact that Germany has today in many ways most advanced urban transportation systems and livable cities.

To summarize, these and other studies have led transportation planners and government officials to a general consensus on the following facts about urban transportation:

relationship of cities and transportation is much more complex than is commonly believed,

to understand complex relationships among technical, economic, social and other aspects in urban transportation, a systems approach, including interdisciplinary expertise is necessary,

there is an increasing need to recognize "livability" or quality of life in cities and societies,

with increasing urbanization, conditions and requirements of cities have a growing impact on world trends in environmental conditions, energy, water, and other supplies, and

all these global problems must be considered not only in a cross-section of present time, but longitudinally, as a future trend which demands considerations and studies of sustainability.

These trends and complex requirements can only be met if cities, particularly medium and large ones, develop transportation systems consisting of several coordinated modes of transportation, each playing its optimal role. This concept of "Intermodal Cities" has been promoted by majority of transportation professionals, and it has been implemented by laws in many countries: the above-mentioned German law from 1967 strongly promoted intermodal transportation systems and emphasized importance of its impact on livability. The French government endorsed the same principles in several laws since the 1970s. In the U. S. the 1991 Transportation Act is designated as Intermodal Surface Transportation Efficiency Act, known as ISTEA [2].

Use of different transport modes is particularly important in medium and large cities. Its advantages over systems relying mostly on a single mode are that they provide greater choice of travel, greater reliability and safety. It allows optimal design and operating efficiency for different services, ranging from high-capacity high-speed metro lines to low-density suburban residential areas relying on private cars and bicycles, *etc*. Finally, intermodal systems are generally superior in achieving livability and sustainability than unimodal systems.

Provision and coordination of different modes is, however, more complex than design and operation of a single mode. It involves different agencies, different methods of financing and payments. In addition to greater complexity, planning and implementation of intermodal systems requires greater professional expertise and, often, protection from special interest groups and lobbies. As an example, many countries have legislation requiring energy efficiency and conservation, but in practice, highways continue to receive much greater subsidies than urban transit and railways.

The family of urban transport modes today

The following brief review of transport modes will show that their diversity has increased in recent decades through technical and operational innovations. Urban planners should be familiar with their characteristics to make optimal selections for every urban area considering its requirements and conditions. The main members of the family of urban transport modes and their basic features are defined here [see also refs. 2 and 9].

Walking:

– the basic mode for short trips in urban areas and for access to all vehicular modes,
– environmentally friendly, and
– neglected and suppressed in many car-oriented cities, it has now become recognized as the key component of urban "livability".

Street/road system with automobiles, transit vehicles, trucks, mopeds, and bicycles:

– basic network in every city,
– major features: ubiquity, convenience and low cost,
– traffic engineering, transportation systems management and related operational systems have become very sophisticated, and
– without adequate control, streets can suffer from chronic congestion with many negative externalities.

Bus transit:

– lowest cost transit mode for low- to medium-capacity lines,
– does not compete easily with private auto, except when buses are given preferential treatments,
– upgrading to separated bus rapid transit (BRT) requires substantial investment and control measures, but improves its performance and passenger attraction,

– BRT is being successfully used in cities of developing countries which can implement strict traffic controls, and
– a number of BRT systems have failed because other vehicle categories (taxis, carpools, turning vehicles, *etc*.) were allowed to use busways under political pressures.

Tramway and light rail transit (LRT):
– many innovations in recent decades [10],
– requires considerable investment, but lower operating costs than buses,
– filling the gap: higher performance than bus, lower investment costs than metro,
– built in medium and large cities (since the 1970s, about 20 new systems in North America, dozens in Europe),
– many diverse applications, from major high-speed lines across urban areas to local services in central cities, and
– extremely environmentally friendly: quiet, without exhaust, LRT vehicles traveling through pedestrian areas add livability to cities.

Metro or rail rapid transit:
– requires very large investment, but provides the highest capacity and highest land and energy utilization for high passenger volumes,
– very effective in large urban areas,
– high speed and reliability make it competitive with private car, and
– due to its high performance and permanence of its infrastructure, metro has major positive impacts on urban development and form.

Regional rail (RGR):
– railway-based high-performance long lines serving urban regions,
– highest comfort and reliability make it superior to cars in many corridors, but much more environmentally friendly, and
– electric RGR provide regional transit networks in many large cities (Berlin, Paris, New York, Tokyo).

Photo 4. A modern, environmentally friendly articulated trolleybus (Geneva)

Photo 5. Light rail transit contributes to livability of pedestrian-oriented central cities (Karlsruhe)

Paratransit (taxi, jitney, minibus), automated guided transit (AGT) and specialized modes (ferryboats, funiculars, monorails) supplement this diverse family of modes. Well-planned large cities utilize several of these modes operationally and organizationally integrated into balanced intermodal systems.

Achieving optimal balance among modes

Photo 6. Metro, the highest-performance transit mode, has a major impact on sustainability of cities (Washington)

Selection among different transit modes, such as bus, LRT, and metro, is complex and requires considerations of many technical, operational, and economic factors. However, in recent decades most cities have faced the above discussed much more fundamental dilemma – the decision about the role the private auto should play and the relationship between auto and transit. Excessive reliance on the private auto has given short-term satisfaction for auto users – an excellent degree of mobility. However, in the long run, auto-dominant cities have proven to be neither economically sound, nor very efficient even with respect to personal mobility: congestion leads to decreased level of service even for auto users; at the same time it causes deterioration of transit services and inconvenience for pedestrians.

These developments have led many cities to realize that simply continuing past trends was not a viable option because growing auto ownership would lead to further worsening of traffic congestion and decay of cities, which would be again accelerated by suburban and exurban sprawl. Thus, there will be a continuous deterioration of cities' economic, social, and quality of life conditions. The main problem is then how to achieve transportation systems which consist of a set of modes which are most efficient in their roles and which are mutually integrated. This type of coordinated intermodal transportation is referred to as a *balanced intermodal system*. Its main immediate goals are to maximize mobility (or, more precisely, accessibility) while causing minimum negative impacts on the city's economy and environment.

The most critical balance that must be achieved is between two basic mode categories – auto and transit. That problem is very difficult because the balance between these modes requires solving the difference between two different conditions, defined by [11]:

– "individual equilibrium" (IE), is the condition when each traveler selects the mode he/she considers the most advantageous, and
– "social optimum" (SO), is the intermodal distribution of trips which results in the minimum travel time and cost for all travelers together.

These IE and SO conditions are in real world very different, and system efficiency can be greatly increased if travel between these two modes is shifted from IE toward SO. Such a shift can be achieved by two sets of policies and measures:

– *Transit incentives*: building networks of high-performance, competitive transit systems, fare innovations, better attitude toward passengers, marketing, *etc*.; transit incentive measures are easily justified and popular, and
– *Auto disincentives*: traffic reduction measures, economic policies (parking rates and structure, road pricing); auto disincentives are justified and rational, but politically challenging because they represent restrictions to or discouragement of travel by car.

The diagram in fig. 1 shows these conditions graphically. Total disutilities of travel, consisting of travel time, cost, inconvenience, *etc*. for a given number of trips is plotted for both modes. For auto travel, the disutility, plotted from left to right, increases with travel volume. The disutility for transit travel, on the other hand, decreases with travel volume, because transit ser-

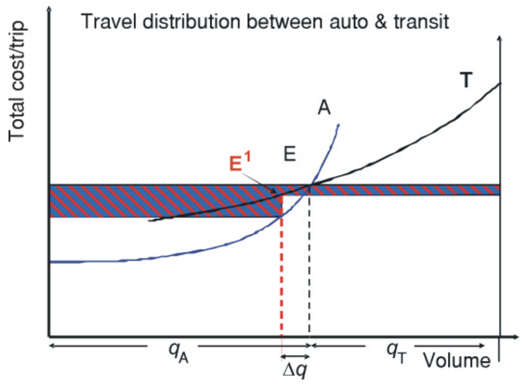

Figure 1. Private auto – public transit intermodal balance diagram;
A – automobile trips, T – transit trips, E – equilibrium points, q – travel volumes [trips/times]

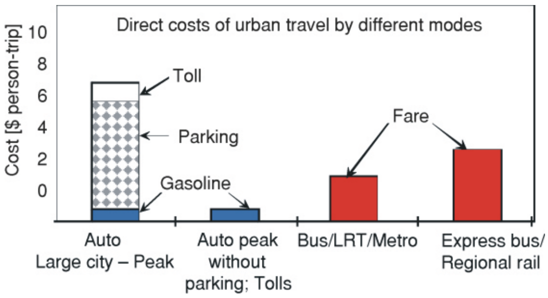

Figure 2. Comparison of out-of-pocket costs of travel by different modes

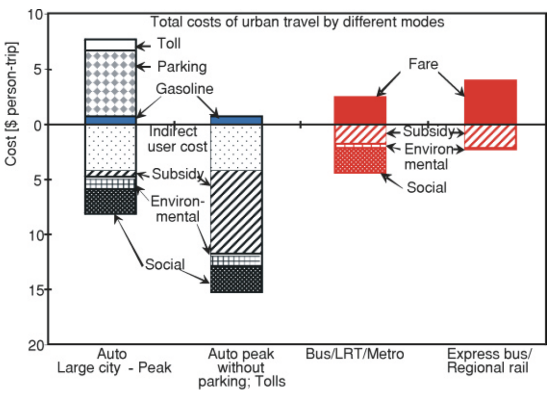

Figure 3. Comparison of total, direct, and indirect costs among different modes

vices are better when passenger volume is greater. This curve is plotted from the right ordinate to the left.

The intersection of the two disutility curves represents the division between the two modes when individuals select their own optimum mode. A shift from this point to the left would result in decreases of disutilities on both modes (it would change the division from IE toward SO), but individuals would tend always to return the situation at the initial IE point because they personally gain by such a change, although total system disutility increases.

A major problem in the distribution of travel between autos and transit is the fact that auto users pay extremely low amount of charges for their travel directly, “out of pocket”. As the diagram of such costs of travel by different modes, shown in fig. 2, shows, direct out-of-pocket costs for auto are often even lower than the fares for transit travel. This is particularly extreme in the U. S.

The basic problem affecting intermodal distribution of travel is that vast majority of travel costs by car are fixed, not directly related to individual trips or their lengths. Actually, in the U. S. drivers’ out-of--pocket costs represent only about 15-20% of the total car owner’s cost. The fixed costs, including depreciation, maintenance, insurance, *etc.*, amount to 80-85% of costs. Moreover, external costs every auto traveler imposes on others, such as social (congestion), environmental, accidents and others, are not charged to the traveler at all, so that he is not interested in reducing them.

Costs of travel by auto, together with costs of travel by transit, are shown in fig. 3 as bars with user direct out-of-pocket costs above the horizontal line, and his fixed costs as well as the externalities each car trip involves, *i. e.* costs affecting others, are plotted below the horizontal line. The diagram clearly shows that all indirectly paid and unpaid costs, those below the horizontal line, have very different amounts among the modes.

It is obvious that when urban travelers compare their direct costs among alternative modes of travel, their choice is biased toward auto. However, such a decision results in much higher total costs to the traveler, and, moreover, they involve very high costs to other travelers. This situation and conditions for drivers' intermodal choices represent the core of the problem of traffic congestion and the "collision of cities and cars" phenomenon.

This problem of very low direct costs for auto travel can be corrected by higher parking charges, gasoline (petrol) taxes, by road pricing and similar measures, which have begun to be increasingly used in several countries in recent years.

Examples of success: Singapore, West European, and some North American cities

In many cities general public opinion, and even statements of some public officials, express skepticism about chances for improvement of transportation conditions. The skeptics point out at powerful lobbies which oppose changes, inability to achieve consensus about investments and policies, and the underlining problem of inadequate understanding of the complex urban transportation problems by the public which elects public officials.

However, developments in a number of cities during the recent decades clearly show that with sound transportation policies, coordinated political and technical leadership and well-informed public, it is possible to replace chronic transportation problems of congestion and its negative impacts by efficient transportation systems that provide stimulus to urban growth and livability. A few examples will be described here.

Germany has greatly benefited from the laws about urban transportation adopted by its Parliament (Bundestag) in 1967. Based on the recommendations of The Committee of Experts [8], German cities have steadily invested in parallel improvements in road/street and transit networks. To achieve balanced transportation, transit has largely been given favored position compared to general vehicular traffic. As years past, the role of pedestrians became reaffirmed, and virtually all German cities, from small historic towns to large metropolises such as Munich, Köln, and Berlin have developed a mutually supporting symbiosis between pedestrians and transit serving directly the cores of cities. Use of modern light rail systems in pedestrian zones is the most typical example of this intermodal system making cities livable.

Singapore was in 1970s among the first cities which began to apply physical, regulatory, and pricing measures to coordinate use of different modes into a balanced intermodal system. Singapore was the first city in the world to apply road pricing for driving cars into center city in order to decrease congestion. The success of this measure led to the use of the next generation of road charging method, Electronic Road Pricing. This is a regulatory system for dynamic control of traffic flow. In addition, this auto use disincentive measure was paralleled by major improvements to its transit system. A major metro system was built and is continuously extended. Bus system has been reorganized to have many transfer points and major terminals at metro stations. In addition, several automated guided systems have been built to serve for access from high density residential areas to metro stations.

A particularly important element in this comprehensive approach to all modes of transportation in Singapore was the founding of the Land Transport Authority (LTA), a government agency which has high level of expertise in planning and operations of transportation systems of all modes. This organization has the task to provide coordination of all transportation modes and their interaction with urban planning.

Toronto reorganized its administrative boundaries in the 1970s to achieve more effective regional government than most cities in North America have. It has consistently upgraded its transit system through construction of a metro network coordinated with high-density land use developments around its stations. Its extensive tramway network, for which extensions are now planned, and its buses have connections with the metro at very imaginatively designed transfer stations with good weather protection to cope with severe winters. With its transit and freeway networks and extensive pedestrian zones in its center and many suburban centers, Toronto is considered to be one of the most livable cities in North America.

Portland, Ore., USA, and *Vancouver, B. C., Canada* are medium-sized cities that have also pursued comprehensive land use/transportation planning balancing auto traffic, transit and pedestrians. With their larger counterpart San Francisco, they also enjoy the reputation of very livable and sustainable cities.

Photo 7. Examples of livable cities: aesthetically pleasing highway with free-flowing traffic (Singapore)

Photo 8. Pedestrian-oriented center city served by bus, trolleybus, LRT, metro, and cable car modes (San Francisco Market Street)

Photo 9. Coordinated land use-transportation planning: high-density developments around metro stations (Toronto Yonge Street corridor)

Conclusions and lessons for the future

In summary and in perspective, the last century has brought tremendous technical advancements. Yet, presently serious organizational problems exist, such as:

- complexity of transportation system is often not understood,
- basic goals and policies are seldom clearly set, and
- transportation impacts on cities – their economy, quality of life and sustainability – are often underestimated.

Cities which have made good progress in developing efficient transportation systems without negative impacts on urban living provide the following lessons:

- for efficiency and good services, intermodal systems must be achieved through integration of modes and implementation of policies that achieve their optimal balance,
- progress in technology must be complemented by organizational innovations,

- while technological innovations continue to be important, *understanding of problems and introducing innovative policies are usually the critical steps toward solutions*,
- transportation requires an interdisciplinary, systems approach, rational transportation policies, comprehensive planning and effective implementation, and
- public support is needed to overcome institutional barriers and special interest groups.

Taking a broad systems approach to planning and operation of cities, the following observations about overall goals in urban transportation are particularly relevant:

- the goal in transportation planning should be not only efficient transportation, but creation of livable, sustainable cities with good quality of life,
- as a vital service in cities, transportation must be coordinated with other functions, such as economy, social conditions and quality of life,
- achieving these goals is a continuing challenge for government officials and transportation professionals, and
- again, at this highest level of societal goals, well-informed public generally supports balanced policies toward intermodal transportation system and livable cities. Education of the public is therefore an important task not only for political leaders, but also for professionals in urban and transportation planning.

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