Sustainable Urban Transport System

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Abstract: Transport development aims at reducing time and energy, hence costs on travel and transport, thereby improving people's access to resources, markets and services. Much of the transport development benefits are inequitably distributed both spatially and socially. The cities differ in nature of air pollution due to the specific characteristics of pollutant sources and the fuels used. However, in most cases transport is the main source of urban air pollution (World Bank, 1996). In large metropolitan cities road traffic may account for more than 90 percent of lead and carbon monoxide, 60 to 70 percent of nitrogen oxides and hydrocarbons, and a major share of particulate matter. Urban transportation provides access and mobility for people and goods within cities. Urban transportation system consists of different components which include public transit (collective transport), private transport, non-motorised transport (pedestrians, cyclists) and freight. Effective urban transport systems are indispensable for efficient economic activity and better quality of life.

Introduction
Traffic and travel pattern of people differ greatly from city to city and from country to country. This is based on the differences in the social, political, economical as well as cultural differences of the population. Historically mobility and accessibility to the transport system have been playing a major role in shaping cities. It facilitates social and economic activity by trade, permitting access to people and resources, and enabling greater economies of scale. Further mobility and accessibility expand cultural and social connections, increase employment, and educational as well as healthcare opportunities. The pollution level of some Indian cities in comparison to other cities in the world is shown in Table 2.1.

Table 2.1: Large cities exceeding WHO pollution levels at the global level

<table>
<thead>
<tr>
<th>City</th>
<th>Lead</th>
<th>CO₂</th>
<th>NOx</th>
<th>Ozone</th>
<th>SO₂</th>
<th>PM²</th>
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<tr>
<td>Bangkok</td>
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<td>Beijing</td>
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<td>Bombay</td>
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<td>Buenos Aires</td>
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<td>Kolkata</td>
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<td>Moscow</td>
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<td>Rio de Janeiro</td>
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<td>Sao Paulo</td>
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<td>Seoul</td>
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</tbody>
</table>

Note: ¹90 - 100% from transport sources. ²Carbon-dioxide, 80 - 100% from transport sources. ³Oxides of nitrogen, 60 - 70% from transport ⁴Sulphur dioxide, 80 - 100% from transport sources. ⁵Suspended particulate matter.

Source: Vasconcellos, 2001

Transport development aims at reducing time and energy, hence costs on travel and transport, thereby improving people's access to resources, markets and services. Much of the transport development benefits are inequitably distributed both spatially and socially. In many of the developing countries, people don't have...
access to adequate transport infrastructure and means of transport. According to John Whitelegg in The Guardian (Whitelegg, 2003), air pollution from traffic claims 400,000 lives each year, mostly in developing countries, and daily some 1.5 billion people are exposed to levels of pollution well in excess of the World Health Organisation (WHO) recommended levels. Particulate pollution and levels of cancer-causing pollutants have already damaged the health of hundreds of millions of children. The cities differ in nature of air pollution due to the specific characteristics of pollutant sources and the fuels used. However, in most cases transport is the main source of urban air pollution (World Bank, 1996). In large metropolitan cities road traffic may account for more than 90 percent of lead and carbon monoxide, 60 to 70 percent of nitrogen oxides and hydrocarbons, and a major share of particulate matter.

1. Road Accidents and Injuries

At present 3,000 people are killed and 30,000 are seriously injured on the world's roads every day. These deaths and injuries take place mainly to pedestrians, cyclists, bus users and children. Among them the poor suffer disproportionately from road accidents. In metropolitan cities such as Kolkata, Delhi and Mumbai car ownership is growing at more than 20 percent a year, with little effort has been made to improve the road infrastructure. Advancement in vehicle, engine and fuel technology are of little relevance in the city where the growth of automobiles is dramatic where highly polluting diesel and two-stroke engine vehicles are the maximum (Whitelegg, 2003). Transport infrastructure constitutes barrier against the movement of both vehicles and humans. The biased notion of modernisation is that motorisation brings only congestion, air pollution and traffic congestion (Peters, 2002). The average speed during the peak hours in metropolitan cities is around a mere 17 kmh \(^{-1}\), besides some fatality in the Central Business Districts (CBD). Fatality rates for walking and cycling are extreme during peak hours at 66 and 55 times respectively.

2. Urban Transportation

Urban transportation provides access and mobility for people and goods within cities. Urban transportation system consists of different components which include public transit (collective transport), private transport, non-motorised transport (pedestrians, cyclists) and freight. Effective urban transport systems are indispensable for efficient economic activity and better quality of life. Urban transportation provides access to essential services and social activities (Arasan 2012, Rodrigue et al. 2009, Lu et al. 2009). Business activities depend upon urban transportation systems to ensure the mobility of its customers, employees and suppliers. The urban transport services cover some important social and economic services such as leisure trips, business journeys and trips to various institutions. Effective urban transport fulfils the demand for accessibility within cities (Okoko 2006; Arasan 2012; and Rodrique et al 2009). Further report that transportation infrastructure is one of the key factors that directly affect the efficiency of urban transportation.

3. Supply and Demand

The transport system is closely linked to the socio-economic system in that area. It influences societal and economic processes and in return societal and economic processes indirectly affect the shape of the transport system (Manheim, 1979). Three basic components of transport are:

I. The transport system;
II. The activity system;
III. Traffic and transport flows

The volume of traffic and transport flows is derived from the short to medium function of transport system supply and travel demand. Whereas the traffic and transport flows is based on the longer-term changes in activity and land-use patterns. The flows of traffic and transport might necessitate changes in the transport system itself. Urban transport planning is concerned with this interaction, which is the equilibration of travel demand and infrastructure supply. It intends to steer the process of
allocation of traffic generators and the provision of transport facilities over space and time (Tolley and Turton, 1995).

4. The Impact of Transportation on Productivity

Productivity is the ratio of volume of output to the volume of input. It connotes the extent to which an input is utilized to produce a given level of output. The quality of economic growth and business competitiveness is represented by productivity growth (OECD 2006). Nadiri (1996) argues that investment in transportation is the input whilst the output is Gross Domestic Product (GDP) growth. An effective transportation system is the key in sustaining economic growth in the contemporary economies. An efficient transport system has better capacity to link people to job, deliver products to markets where there is demand, drives supply chain and logistics and enabling domestic and international trade.

5. Traffic Congestion and Productivity

Economically dynamic and vibrant cities will rarely be free from traffic congestion. At present congestion has become an inevitable part of everyday urban life. (May and Marshen, 2007; Yildirim, 2001). There is little consensus on the type of policies that can be used to trade congestion in cities, and that it is unsure that congestion has any clear cut solution. It is interesting that people living in cities have come to accept traffic congestion as part of city dynamics and therefore they have accustomed to it. Some accept traffic congestion in cities is a symbol of a successful socio economic development – improved business activities, increase in employment and improved culture. May and Marshen (2007) argue that congestion impairs people from free movement and that it disrupts business activities in cities and reduces productivity. Congestion affects speed and smooth traffic flow and affects a wide range of activities, services, goods and market opportunities in the cities. Congestion also reduces productivity through increased inventory holding by manufacturers and retailers as a result of unreliable travel conditions within cities. However, freight movement in cities is impaired by traffic congestion, thus making productivity suffer in business activities depending on timely delivery.

6. Sustainable Development

Sustainable development aims at an optimal balance between economic, social and ecological objectives. Sustainability thinking reflects concerns about long-term risks of current resource consumption, keeping the goals of intergenerational equity. Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological investment and institutional change are in harmony and enhance both current and future potential to meet human needs and aspirations. It means the economic and social development that satisfies human needs and aspirations, in harmony with the natural resource base and social equity. The ability of the system to absorb internal and external disturbances to its environment and restore the balance is called the resilience of the system. This resilience relates strong versus weak sustainability. Strong sustainability refers to non-decreasing patterns of environmental and resource stocks over time.

7. Dimensions of Sustainable Development

In a sustainable development context, the objectives related to environmental, economic and social sustainability are inseparable in the short as well as long term. These are furnished in Chart 2.8. Traditionally they were seen as three separate and unrelated parts (diagram a). In the sustainability approach these three parts are integrated (diagram b); where sustainable development is shown in the highlighted area; the interaction between economical, environmental and social development is complete only in the highlighted area. The other overlapping areas can be seen as different paradigms to development, named (1) conservationism, (2) community economic development and (3) deep ecology. Environmental and ecological sustainability deal with maintaining the value of natural systems to
provide goods and services, by respecting the maximum capacity of the (local) environment, conserve and recycle resources and reduce wastes. This is done imposing either a weak or strong view on sustainability. Economic sustainability is concerned with sustaining economic growth by allocating resources, maximising human welfare, expanding markets and internalising costs of externalities, while keeping financial viability. Such externalities exist when the activities of one group of individuals (either consumers or producers) affect the welfare of another group without any payment or compensation on victims (ESCAP-AITD, 2001).

8. Sustainable Urban Development

A sustainable system is described as the one where human potential is exploited for the future without eroding the resource base upon which human beings depend. Sustainable systems like ecological systems are dynamic with many feedback loops to provide self-regulation. It keeps growth of each part of the system coordinated with the other parts as the system (Replogle, 1991). Urban transport put different demands on the issue of sustainable development, (Camagni et al. 1998). Much of the environmental problems originate from cities, such as air pollution, congestion and noise pollution. Many of the urban activities create problems such as waste water flow, waste disposal, and emissions resulting in greenhouse effect and global warming. Therefore urban sustainability policies are the starting points of addressing environmental problems. (Camagni et al., 1998). As poor environmental quality is detrimental to urban economic development, it generates negative stimuli for human health, education and social welfare. Cities are inherently unsustainable because of importing resources, and exporting waste. A sustainable city is seen as the one where environmental, economic and social dimensions interact in such a way to maintain, and increase the quality of urban space. According to Nijkamp and Opschoor (1995), a sustainable city is a city in which agglomeration economies (increasing return in the use of scarce non-renewable resources) should possibly be associated with positive environmental externalities and social network externalities.

9. Sustainable Urban Transport Development

Transport improvements promote economic growth and social development. These are achieved by increasing mobility and improving accessibility to people, resources and markets, however, there have been some concerns about the effect of transport systems on sustainable development. Transport enables development needs of individuals, industries and societies through the provision of basic transport services. Here, transport services consist of quantity of transport opportunities offered (mobility) and quality of access between origins and destinations (accessibility). This is to be achieved in consistent with public health and ecosystem capacity, so as to promote equity within and between successive generations. Sustainable transport development is to integrate economic, social and environmental sustainability. The features of economic sustainability of transport systems consist of:

I. Cost-effective transport services and infrastructure capacity;
II. Financial affordability (to each generation);
III. Support vibrant and sustainable economic activity.

The social sustainability of transport system should possess:

a) Meeting basic human needs such as health, convenience and safety;
b) Allow and support reasonable choice of transport services.

With respect to environmental sustainability, transport systems characterise:

a) Land use pattern has little or no impact on the ecosystems.
b) Usage of renewable or inexhaustible energy sources
c) Emissions and waste regeneration within the carrying capacity of transport systems.
d) Production of noise below the acceptable threshold level of noise pollution.

Environmental effects of urban transport are both local and global. Traffic related air pollution due to carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), volatile organic compound (VOC), and noise have local impacts, whereas carbon dioxide (CO₂), being a greenhouse gas has a serious global environmental impact.

10. Sustainable Urban Transport Development Framework

Sustainable transport development is a dynamic process of harmonious development of sustainability and transport requirements. Sustainable transport system is a transport system that meets the people's transport related needs in terms of mobility, accessibility and safety, within limits of available or affordable environmental, financial and social resource capacities. Most of the interpretations of sustainable transport system have been generally limited to the issues that need to be resolved for transport to conform to the principles of sustainable development and the required policy guidelines. Urban infrastructural development operationalises sustainability by devising performance planning and management. A framework for sustainable urban transport development is a multi-directional concept that includes:

- a) Enhancement of sustainable mobility and accessibility of transport
- b) Use of transport related resources to guarantee intergenerational equity of environmental, social and economic resource capacities.

The first criterion shows improvements in mobility and accessibility as well as equitable distribution of these improvements. This is followed by sustainability related requirements such as wastes production rate and resource-consumption limits. Based on these requirements, the sustainable development conditions are postulated as:

I. Change in well-being of social and economic group
II. Rate of change of environmental resource must not be higher than its environmental capacity.
III. Rate of consumption must not be higher than the resource generation capacity.
IV. Consumption of each resource stock must not be more than the maximum allowable amount of resource consumption.

The implications of the postulates are:

- a. Sustainable development operation in transport infrastructure planning requires, among other things, the knowledge and use of locally defined limits to resources consumption, environmental impacts and levels of transport related well-being in the community;
- b. Different categories of sustainable transport system compatibility need to be differentiated and defined.

A sustainably developing urban transport system is postulated to be one that: (a) is sustainable at any given time period; and (b) delivers, developing levels of mobility, accessibility and safety of movement for all social-economic groups at any given time period. The third and last category is a sustainable and developed transport system.

It is expected that the proposed categorisation of a transport system in terms of sustainable, sustainably developing or sustainable and developed will serve several purposes. For example, it is helpful to describe and explain the differences in the current situations in many cities.

11. Sustainable Development Vs. Sustainable Urban Transport

Internalising principles of sustainable development into traditional transport planning theory is complicated by conceptual differences. Zuidgeest and Van Maarseveen (2000), explain some of the complicating dimensions of time and space as well as focus. Sustainable development implies intergenerational justice
that at least takes up 30 years. Furthermore, transport models mostly give a 'snapshot' projection of the situation in an area at a cross-section in time, whereas sustainable development implies time-dependent models. In contrast most transport models, have limited exogenous inputs, hence sustainability studies are seen in the light of the larger, global system. In other words transport studies are mostly conducted at a local level and to a lesser extent at regional and national levels. Lindquist (1998) justifies using sustainable development at a local transport planning level that most policies are made at the same local level, however, enormity of problems is far beyond the scope of local planning (Camagni et al. 1998). Sustainable development models are multi-sectoral and integral, whereas in transport models impacts of alternative plans are evaluated using performance variables like total vehicle kilometres or total emissions.

12. Accessibility

Accessibility is the potential for interaction or a measure of the intensity level of interactions, (Tagore and Sikdar, 1995). Accessibility to network means the ease of reaching and/or leaving a transport network. The most popular interpretation of accessibility is to express it in terms of the amount of money, time and trouble it costs upon a person or group to cover the distance from their place of origin to their destination. This diversity of interpretations has resulted in the use of many different indicators. The process-indicators are based on the supply characteristics of the system and outcome-indicators are based on actual use and the level of satisfaction. The greatest problem with most of these interpretations is that they do not adequately accommodate engineering characteristics such as capacity and level-of-service supplied by the transport system. Four different components of accessibility identified are (Geurs and Ritsema van Eck 2001):

a. A transport component reflects the disutility in bridging the distance from origin to destination using a specific transport mode;

b. A land-use component reflects the magnitude, quality and character of activities found at each destination.

c. A temporal component reflects the availability of opportunities at different times of the day and the times at which individuals participate in certain activities;

d. An individual component reflects the needs, abilities and opportunities of individuals.

From a strategic modelling point of view, the first two components are essential for an accessibility measure. In that they reflect the characteristics of travel demand and infrastructure supply in an area or the expected demand-supply equilibrium. Hansen (1959), sees accessibility as the potential of opportunities for physical interaction between spatially separated activities by a transport system.

13. Equity

Sustainability is not only about environmental amenity due to transport improvements in an urban area but also about increasing human potential and well-being for all groups in a society. Transport improvements reduce social exclusion hence increase equity. DETR (2002): identified four types of transport social exclusion.

a) Spatial exclusion when people simply cannot get to the location they wish to access;

b) Financial exclusion when they cannot afford to get there;

c) Temporal exclusion when they cannot get there at the appropriate time;

d) Personal exclusion, when they lack the mental or physical equipment to handle the available means of mobility.

The first two components are essential for strategic planning. The extent of these components can be influenced through aggregate supply-side interventions, as capacity and cost improvements to all social-economic groups in the area. The third and fourth type of social exclusion typically involve disaggregate and
operational analysis of transport supply. These components are Litman and Burwell called vertical equity, which implies that accessibility options should improve for people who are economically, socially and physically disadvantaged. Horizontal equity refers to the distribution of negative externalities as pollution as well as costs and benefits amongst causers and non-causers.

14. Transport and Development

Mobility and accessibility contribute to economic and social development. They are the ingredients of a satisfactory life. It ensures the availability of food, health, education and employment if there is adequate means (Owen, 1987). The role of transport for development is a supply-led approach. In the development process, it is the transport, which leads to a widening of markets, increased production and associated multiplier effects (White and Senior, 1983). Another view to this supply-led approach is that transport provision is a response to demand. The type of transport demand is called revealed demand expressed by the trips that are actually made. However, there is an element of latent demand when the existing demand that cannot be satisfied because of inadequacies in the infrastructure.

15. Resource Consumption and Capacities

Sustainable urban transport development requires sufficient resources to shape development. Hence, the development paths of the transport system are limited by financial capacities. The most popular pollution regulation is through setting environmental standards. These standards imply particular levels of environmental concentration for a certain pollutant. They are normally set with reference to some health-related criterion. This criterion is related to the environmental capacity of the system, which can be defined as the capacity of ecosystems to absorb human activity. Targets for carbon dioxide (CO₂) emissions are often stated as reductions in the cumulative share of transport in CO₂ emissions. Environmental capacity objectives can be formulated for one, possibly dominant, proxy for a pollutant, or a weighted combination of several pollutant types. It is also possible to define specific targets for emission reductions for transport systems in demarcated geographical areas in terms of the local environmental transport capacity. It is the maximum transport capacity in order to consider a transport network acceptable in terms of the environmental objectives. This objective is reciprocal to the environmental capacity objective. It should be noted that these data-points can be derived by simulating route choice behaviour and environmental effects by introduction of Advanced Traveller Information Systems (ATIS).

16. Measures for Controlling Transition Paths

Several transport policy measures are identified for transport planning activities, often combined in an integrated approach. In an extensive study, by May and others (2001), some 60 transport policy measures have been categorised in groups. They are:

I. Land use measures;
II. Infrastructure provision;
III. Management of infrastructure;
IV. Information provision;

Demand-side options are generally influencing the generalised cost of travelling through out-of-pocket costs hence controlling total motor vehicle travel demand. The other factors influencing are road use fees and parking tax, vehicle ownership and acquisition taxes and inducements for ride-sharing and telecommuting (TRB, 1997). Supply-side options deal with availability of transport options and capacity in the transport network such as investment in public transport and non-motorised transport modes and highway capacity and traffic flow improvements and intelligent transport systems (ITS) technology (TRB, 1997):

17. Complex Transport Policy Objectives

Most of the goals and objectives in transport policy and planning are very hard to realise. The essence of a sustainable mobility development is to facilitate the interaction needs
of people and freight mobility. The constraints to achieve this objective are efficient use of scarce resources, equity to all groups of users and observance of capacity limits of external effects, like safety, liveability as well as environment.

Transport planning rarely optimises multiple objectives. Goodwin (1999) opined that the objectives during the decades of predict-provide the formulation of a suitable policy was easy. The classical four-step transport planning model gives a suitable policy to build enough roads according to the predictions of growth. Dependent on the decision-making approach for a sustainable urban transport policy analysis can be applied to obtain better insight and understanding of problems with complex objectives in several ways. Morgan and Henrion (1990) give three suggestions for achieving these objectives. First, the authorised decision-makers have well-defined goals or objectives to determine how best to achieve these complex objectives. Secondly, in some cases alternative policy options are clearly established to assist the decision maker in choosing among a discrete or continuous set of options. Thirdly, policy analysis is used to help the decision maker to identify and explore possible alternatives to choose among them. In transport policy analysis, decision makers are also confronted with an increasing number of complex transport policy objectives and planning restrictions. A transport planning method that can assist in determining sets of transport policy measures, which give maximum value to these transport policy objectives, hence designing a transport planning will prove to be useful.

18. Existing Optimisation Models

Optimisation techniques have been applied extensively in transport science and traffic management studies. A great body of literature exists on traffic assignment techniques, dynamic assignment techniques on transit assignment and on transport network design(Ortuzar and Willumsen, 2001); (Friesz and Bernstein, 2001); (De Cea and Fernandez, 2001); (Sheffi, 1985; Bell and Allsop, 1998; Yang and Bell, 1998; Bell and Iida, 1999; Nagurney, 2000). Optimisation is common in the field of transport economics. In The Economics of Welfare (Pigou, 1932) introduced the idea of a congestion toll by coming up with the famous two-road example. This was considered as the first transport optimisation model. This approach has been studied extensively and many different models have been made in connection with this idea. Optimal road pricing measures are the output of these models. Timothy Hau presents a model that studies the theoretical benefits of road pricing based on the above economic principles. As Hau's method is only graphical and not based on known parameter values. It is perhaps less suitable to a policy maker who wants to formulate an alternative for a particular transport system. Indeed most models in transport economics have the problem that they are less suitable for modelling in a real world situation.

19. Transport Planning as an Optimisation Problem

Willson (2001) opines that transport planning cannot be considered as a rational reasoning as in a measure of optimisation. Richard Willson describes that the decision-making process in transport planning is one of group decision approach involving negotiation, bargaining and compromising. Hence it is different from optimisation. Because of all the political interests involved in the whole process of transport planning, Willson claims it is better characterised as a communicative process (Willson, 2001). Roozenburg and Eekels (1998) view designing as a creative process with no single best solution resulting in a good design. They also show that it is theoretically impossible to deduct, on the contrary, Andersson (2001), claims engineering design is essentially an optimisation problem as long as some human or unquantifiable judgement is allowed at some stage. Willson (2001) argues that these transport models are less suitable for transport planning. However, it is possible to make an optimisation model such that it can positively handle most of the criticisms. In fact, policy makers have to negotiate with stakeholders and even work together with them as in a group in the decision making process.
20. **Sustainable Transport Models**

Several approaches can be found in sustainable transport management having different interpretations of sustainability. Hence, sustainability is weakened and therefore fundamentally different from the standard forecasting approach in transport planning.

A distinction can be made between the following four methods and modelling approaches:

I. **Sustainability indicators**, which are used to indicate a target value for a certain sustainability variable or combination of sustainability variables;

II. **Scenario techniques** are concerned with analysing the future impact of certain scenarios, or future images to the present situation along transition paths using scenarios;

III. **Static optimisation**, which is concerned with optimising transport networks for a given network topology and travel demand, using variables such as road pricing;

IV. **Dynamic optimisation**, which is used to find transition paths to optimise a transport network over time.

21. **Indicators for Transport Sustainability**

Indicators are central to the monitoring and reporting of progress towards certain public issues. Collectively indicators can measure the capacity to meet the present and future needs. Furthermore, they are often easy to communicate, which is very relevant to the policy process. Standard use of indicators to measure and monitor transport performance is done frequently through indicators like level-of-service, traffic speeds, price of parking convenience, and accident rates per vehicle-kilometre. For measuring sustainable transport development, indicators related to economic, social and environmental sustainability, such as total vehicle kilometres, total motorised movement of people and use of fossil fuel energy for all transport. The use of single indicator is the difficulty of measuring the ‘overall’ sustainability of a transport system. To obtain an overall sustainability index, multi-criteria analysis (MCA) techniques can be used. Oude Moleman (2001) shows how this can be done in practice for analysing and monitoring sustainable transport development, combining the regime MCA method within a Delphi analysis. The Compass Index of Sustainability which clusters indicators and assessment scores into different sustainability quadrants. (Daly. 1991; Meadows 1972)

22. **Static optimisation**

Optimal and operator optimal network designs have been the topic of many researches. Since then the design process is often seen as a bi-level programming problem involving an upper-level supply problem, and a lower-level demand problem. The leader has prior knowledge of the responses of the followers, which is also know as a Stackelberg game (Stackelberg, 1934). Bi-level formulations have been applied many times in transport research recently, amongst others in traffic control design (Chiu 1999) traffic assignment algorithms (Jayakrishnan et al.1995) origin destination table estimation (Yang 1995), road pricing (Constantin and Florian 1995) and network design (Yang et al. 2000). Applying the static bi-level optimisation techniques to derive sustainable transport network can be seen as having upper-level sustainability while complying with the lower-level behavioural rules of the travellers in the system. Variational inequality theory provides a framework for the study of one-level equilibrium problems. For modelling the sustainable transport optimisation problem, variational inequality theory has been extensively applied. A transport network is sustainable only if the flow pattern satisfies the conservation of flow equations. It should not exceed the environmental quality standards subject to the operating behaviour principles (Nagurney, 2000). Transport policies are meant to direct transport networks to sustainability. The policies include emission pricing, introduction of tradable pollution permits as well as introduction of new modes.

23. **Dynamic Optimisation**
The `traditional' equilibrium models assume traffic in the optimal network design is in a static user-equilibrium, and that changes through decision variables do not induce transient effects. However, in sustainable urban transport development, a time-varying nature of travel demand and infrastructure supply in the network seems obvious. Hence, dynamic optimisation models take into account both on time-varying nature of transport networks and disequilibrating effects. Furthermore, dynamic modelling of transport is said to have some additional advantages over static modelling as the absence of the so-called temporal Braess paradox. In addition, dynamic optimisation allows for determining the paths of control variables and state variables for the dynamic disequilibrium system over an infinite or infinite time horizon to maximise an objective function. Hence, dynamic optimisation is also called optimal control (Friesz and Fernandez 1979). Friesz and Shah (1998) discuss the theory of disequilibrium network design and use this in a model to maximise social welfare in a transport system.

24. Conclusion

The description of sustainable urban transport development problem is related to the formal characterisation of the sustainable transport development problem. The conceptual development makes a distinction between the model equations, the applied optimisation method and computational aspects. Mobility of people and goods is an essential prerequisite for social-economic development. In most cities motorised vehicles, notably cars and trucks, have become the most important means of mobility, at the cost of non-motorised transport as well as public transport. The negative images of cities form a serious threat to enhancing social-economic opportunities. Hence, the attractiveness of cities is at stake, the number of transport-deprived people rises and health-damaging effects have become a serious concern. Large investments in infrastructure supply and travel demand are necessary. Therefore, a vision for a sustainably developed transport system needed to be developed. On the one hand where person transport, accessibility, quality of life, environment, congestion, equity etc have an important role, while on the other it is necessary to take care of the generations ahead in terms of financial and environmental capacities. It is claimed that adequate transport systems can only be obtained by the use of the new sustainable transport paradigm and accompanying analytical framework. Hence, the need for a renewed analytical framework for transport planning, where requirements for sustainable development, in terms of environmental, financial and social considerations, are internalised, has been identified. Apart from their proven usefulness in the decision-making process, these models are also known for having several shortcomings as lacking possibility to explicitly incorporate transport policy objectives, accessibility, land-use feed-back, travel demand elasticity etc, especially when it comes to issues of sustainable development.

References


