An approach to the development of sustainable urban transport system in Kolkata

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The existing transportation system in most of the cities of the world experiences numerous traffic and environmental problems such as severe traffic congestion and road accidents coupled with air and noise pollution with a cascading effect on human life. More than a million people are either killed in road accidents or die due to severe air pollution in the world. Gasoline-based transportation system is one of the major problems making the existing transportation system very unsustainable. In view of this, an attempt has been made here to explore the possibilities of finding a possible approach to the development of a sustainable transport system. Traffic problems in various cities and the methods adopted to mitigate the problems have been discussed. A case study in Kolkata was taken up to appreciate problems and issues of the existing transport system which is increasingly becoming unsustainable. Based on earlier studies, an approach to make the transport system sustainable for Kolkata has been suggested.

Keywords: Air pollution, noise pollution, transport demand, urban transport.

Introduction

MAN has made excellent progress in every sphere of activity including launching satellite vehicles into the earth's orbit. A tremendous advance in transport technology has been increasingly made at urban, regional, national and international levels. This has enabled the present system to progress from the manually driven bicycle to a driverless advanced rail transit system and computer-guided aircraft.

Rapid increase in population coupled with numerous socio-economic activities is a constant source of increasing pressure on the limited natural resources and a constant threat to sustainable development in the urban areas. The present form of transport system consisting of private and public transport has emerged as a result of intense development in the urban areas and offers both merits and demerits to our system of development. Increased mobility is the primary expression of the benefits that the society enjoys due to the transport system. This also acts as a catalyst for the deterioration of the environmental quality in terms of noise and air pollution. It is a major concern for sustainable development in the urban areas.

Gasoline-driven vehicles are the major pollutants, making the environment unsustainable for healthy growth of the cities. According to studies carried out in Delhi, the city experiences high levels of air pollution of more than of 2000 tonnes per day and noise pollution beyond the accepted prescribed limit in most of the congested parts of the city.

In light of the severe air pollution, it is imperative that immediate action has to be taken in order to keep the urban transport environmentally sustainable. The following sections highlight some of the major issues of the environment and the transport system, and explore the potential/prospect and constraints/limitations through consideration of transport and environment problems in many cities in the world, which would help in sustaining the development in future.

The concept of sustainability is to be understood at a global level rather than national or local levels which would require various dimensional problems of the third world countries.

In the context of the urban transport sector, car and lorry may be considered to be symbolic of the central problem of non-sustainability. The movement of these vehicles along with other personalized motorized vehicles in the urban area bears significant impact on the environment and is responsible for the greenhouse effect and is a serious health concern. This is the central issue for understanding the problem of sustainable development.

Sustainability

Concept of sustainability

The World Commission on Environment and Development[1] has clearly defined the concept of sustainable society as one 'that meets the needs of the present without compromising the ability of future generations to meet their own needs'. There is a school of thought which spells out the following conditions for ensuring a physically sustainable society.

- Its range of pollution emission does not exceed the assimilative capacity of the environment.

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- Land value should not exceed more than four times the construction cost.
- Availability of water.
- Sustainable transport refers to any means of transport with low impact on the environment, and includes walking and cycling, transit-oriented development, green vehicles, car sharing and building or protecting urban transport systems that are fuel-efficient, space-saving and promote healthy lifestyles.

Rapid growth of population coupled with numerous economic activities has placed a substantial demand for energy for all sectors of economy. The primary question is how best can we optimize the limited natural resources available for the present and future in order to keep the environment safe. In light of the above aspects, an in-depth understanding of sustainability can help avoid a global catastrophe by careful stewardship of the limited opportunities that nature provides for controlled growth. According to Hajer[2], sustainability is not only an attempt to provide solutions to improve the objective state of environment, but also an effort to accommodate latent social conflict. Sustainability also refers to the reduction of greenhouse emissions caused by high levels of air pollution

Transport Agenda – 21

The 'Earth Summit' in June 1992 held in Rio, Brazil has identified transport as one of the key areas responsible for the deterioration of environmental quality. The impact of transport on our society is well understood through a wide appreciation of the links, among consumption, economic growth, environmental impact and sustainability. Transport Agenda 21, as discussed and documented in the Earth Summit, presents some of the major changes taking place in the society which are likely to significantly affect the travel demand of this century. It identified three major issues that relate to demographic change, technological change and infrastructure requirement. It has been increasingly felt and argued that the Agenda 21 for transport planning must address all the three issues.

Urban transport problems and solutions

Most of the major cities in the world are increasingly confronted with numerous traffic problems leading to a high level of traffic congestion coupled with a considerable number of road accidents. The problems of traffic are primarily attributable to innumerable factors such as high intensity of private vehicles on the roads, poor mass transportation facilities, inadequate road capacity, heterogeneous movement of traffic, etc. While highlighting the problems of traffic as experienced by major cities in the world, it would be worth mentioning the unfriendly modes of transport causing severe damage to the environment. A brief review of major cities in the world experiencing severe traffic problems with the adverse effect on environment is discussed here.

Bangkok

The city, being the capital of Thailand, experiences unplanned and uncoordinated development with 9 million population characterized by massive urban sprawl radiating up to 50 km in all directions and its traffic condition is recognized as being among the worst in the world. Average travel speed on most of the roads have come down to 5 km/h from 10 km/h with the growth of traffic between 15% and 20% per year on the road network occupying 11% of Bangkok's total land area. Presently, it has improved the transport system for catering to a high travel demand.

Lagos

This city is one of the fastest growing urban centres in Nigeria having the largest commercial, industrial and financial base and a total population of 5 million within an area of 1800 sq. km. There are a large number of traffic problems of which traffic management, transport coordination and expansion of transport services are yet to be resolved. Inadequate mass transport services has resulted in such a situation that 80% of the estimated 35,000 used imported vehicles are operating as public transport services known as Kabu-Kabu. It is estimated that over 250,000 vehicles and 2 million passengers enter and leave Lagos and the adjoining areas every day. Besides this, poor urban rail transport exists on a stretch of 20 km. According to the estimates, the public road transport would share between 80% and 85% of the total trips.

Santiago de Chile

Due to rapid growth of the vehicle population increasing between 6% and 10% annually, the city had 405,000 vehicles according to the survey carried out in 1991 which was almost twice the number recorded in a survey in 1977. This has resulted in serious problems of inadequate road capacity. In addition to this, high level of car ownership among only 16.7% of the city population made a tremendous impact in generation of passenger trips from 0.4 million to 1.34 million between 1977 and 1991 – a 350% increase in absolute terms.

Although the deregulation of the city's bus service was a good move leading to a bus fleet increase from 5200 to 10,500 between 1979 and 1989, there were serious and harmful consequences in terms of competition among the buses and increase in traffic problems due to the absence of any regulated bus stops, routes or trip frequency.

In 1989, the National Commission for Energy in Chile organized a pilot programme with the objective of verifying under local conditions, the conversion costs, energy efficiency and impact of using cleaner fuels in public transport buses on the air pollution in Santiago. The five alternative fuel options tested were liquefied petroleum gas (LPG), methanol, gasoline, compressed natural gas (CNG) and diesel. It was observed that all five options were effective in reducing particulate emissions, with the highest reduction achieved with LPG, CNG and methanol. An economic evaluation of all alternative fuel options for Santiago buses confirmed that diesel fuel buses had strong competitive advantages while CNG buses could become competitive. This evaluation demonstrated that LPG, methanol and gasoline-fuelled buses were more expensive as compared to diesel fuelled buses or CNG fuelled buses, hence were unlikely to take up a substantial part of the market share.

Amsterdam, Netherlands

The city was not designed for cars as in most old cities of Europe. Car traffic was not a significant problem until the 1970s as the network along the extensive canal system was well developed. With an increase in car ownership, public transportation slowed down from the early 1970s. One of the major problems was the on-street parking demand exceeding the meagre supply of parking spaces. Over a period of time, it has been able to improve its transport system and make cycling very attractive due to a well-planned bicycle network.

Havana, Cuba

Until 1990, Havana, the capital of Cuba, was mostly dependent on mass transportation facilities. After the disappearance of the extensive network of electric trains and trolleys, buses were the key mode of public transport system. In 1990, Cuba faced a tremendous economic crisis when the socialist block broke off economic relations and sugar and nickel prices (the country's main export) fell sharply from US$ 8 billion in 1989 to only US$ 2 billion in 1992 (ref. 1).

This economic crisis was responsible for adopting a policy of encouraging bicycle usage in the country. It is noteworthy to mention that Havana's 70,000 cycles used solely for recreation and sport in 1990 shot up to 770,000 by 1993 resulting in the reduction of bus traffic and cars by 50% and 35% respectively. The city finally turned into a bicycle city.

Lima, Peru

For a population of 3 million, Lima is not an exception where traffic congestion, air pollution and irregularity of bus services in low-income areas do not exist. Besides high level of traffic congestion and air pollution caused by cars, trucks and buses, accident rates are also high with about 70% of total accidents resulting from vehicle–pedestrian accidents. Studies also indicate that half of the residents with low incomes between US$ 208 and US$ 80 cannot afford to use the public transportation system due to its expensive fare structure.

Buenos Aires, Argentina

Argentina has also experienced the problems of air pollution due to high growth of its vehicle population. In order to overcome the problem, in 1985, a programme[3] on tax exemption was introduced in Argentina to promote replacement of petroleum fuels by CNG. Mid-sized trucks and taxis quickly adopted the programme. By the end of 1994, about 210,000 vehicles in the Buenos Aires Metropolitan Region were converted to CNG usage. Of the nearly 40,000 officially registered taxis, about 65% use CNG, with the remaining running on diesel; of the 15,000 registered buses, only 300 run on CNG. CNG has substituted 12% of diesel use in the region. This has resulted in reduction of 6% particulate emissions. Taxi owners generally prefer the CNG-fuelled cars because its nominal cost is lower than diesel and is substantially less than the price of gasoline. In spite of the advantages of CNG fuel, the potential shift of buses from diesel to CNG is limited mostly due to the inconvenience associated with refuelling. The fuelling time for CNG is very long. CNG-fuelled vehicles emit no lead and generate lesser NO_2, CO and HC than gasoline-based vehicles as exhaust. CNG-fuelled vehicles are less fuel efficient than gasoline-based vehicles due to the extra weight of the cylinders.

Brazil

Owing to the shortage of ethanol in 1990, an extensive investigation was made for new, viable fuel solutions. A new fuel blend of 60% hydrated ethanol, 33% methanol and 7% gasoline by volume was identified as a suitable substitute for ethanol in original equipment manufacturer vehicles designed to run on ethanol and gasoline mixtures.

The addition of methanol tended to compensate for gasoline that resulted in leaner air–fuel ratio and low calorific value. Finally, this ethanol–methanol gasoline blend helped meet a critical fuel shortage without compromising on the country's vehicle pollution control programme.

Kathmandu, Nepal

Kathmandu suffers from severe air pollution due to vehicle emissions and has provided the ideal circumstances for

introduction of zero emission electric vehicles. With a population of approximately 1.5 million people, the city occupies a small area. The distances travelled are quite short. Speed hardly exceeds 40 km per hour.

The Global Resources Institute initiated the first phase of the electric vehicle programme in Kathmandu in September 1993 with the conversion of diesel three-wheeler to electric power. Based on the continued efforts for conversion to electric vehicles, the ongoing work is focused on developing a sustainable electric vehicle industry in Nepal.

Since its inception in September 1993, Safa Tempo is the local generic name for the three-wheeler and it has been widely accepted, recognized and supported by the public. Other cities in South and East Asia are aware of the developments in Kathmandu.

New Zealand

In order to ensure a programme for clean air, the New Zealand government launched a CNG programme in 1979 aiming to convert diesel-fuelled vehicles to CNG by the end of 1985. By 1986, 110,000 vehicles (11% of cars and light trucks) had been converted, and New Zealand had 400 filling stations at that time. The price advantage of CNG rose to a maximum in 1984, when CNG costed about 40% of the price of gasoline.

Denmark

The Denmark Government focuses on three types of new vehicles – hybrid, battery electric and fuel cell – and plans to develop key technologies of battery, motor and electronic control systems. The '1000 + green vehicles in each city' technology promotes large-scale commercialization of new energy vehicles in the public transport systems making hybrid, electric and fuel cell buses and taxis available, initially in 13 cities. By 2012, over 60,000 clean buses and taxis are expected to be plying in Denmark.

The government has a long-term vision of making Denmark completely independent of fossil fuels. The first step has been taken, introducing a new strategy for sustainable transport, designed to 'break the curve' of emissions. Denmark's green transport policy has been formulated with the overall objective of improving mobility while reducing transport-related CO_2 emissions in a cost-effective way.

One cannot ignore the fact that transport is responsible for some 25% of Denmark's CO_2 emissions, a figure expected to rise in the coming years. The government intends to reverse this trajectory. But as it endeavour to do so, it must not lose sight of the contribution transport makes to its quality of life – connecting people, families and businesses.

The 'green transport vision DK' is a far-sighted, integrated plan for a green transport system, with three fundamental components:

- Adjusting vehicle tax to greener vehicle levies
- More and better public transport
- New sustainable technologies.

It will bring down the rising CO_2 emissions from transport as it approach the year 2020.

Judicious restructuring of vehicle tax to greener vehicle levies will accelerate the development of a more energy-efficient national car fleet and the phasing-in of cleaner technologies – with zero or minimum use of electricity as fuel. Cars are essential to many Danes, for the smooth running of their daily lives, and they will remain important in the future. But they are now making energy-friendly cars cheaper and introducing smart road pricing to motivate people to drive when the roads are at their emptiest and to consider when it might be wiser to go by bicycle or public transport. This, combined with such measures as smart traffic control, will reduce pressure on the roads. Congestion is already a problem on some stretches, with inevitable loss to the economy.

Denmark will, therefore, significantly extend and improve its public transport, providing more trains, at more regular intervals and with shorter journey times. This massive investment in public transport will go hand-in-hand with the green re-adjustment of car taxation.

The 'big picture' envisages efficient electrical cars within a few years. Hydrogen and electricity-potheyred cars are exempt from tax until 2012, and in the period 2012–2015, an advantageous registration fee will apply to electricity-potheyred cars, commensurate with what is needed to maximize their take-up. And if enough drivers make environmentally friendly choices, both when buying and driving cars, they shall have made great strides as a society towards ceasing to be dependent on fossil fuels.

Denmark is also to act as a 'laboratory' for developing sustainable transport technologies that they can feed into – and play a major role in – the transport system in the long term. It is important that international partners see the country as an attractive place for trying out new

Figure 1. Reserved lane for bicycle traffic in cities in Denmark.

technologies, so pilot projects will be set up over the next few years to identify opportunities for, and obstacles to, disseminating new technologies and making them marketable. These will test the deployment of energy-efficient transport solutions, such as energy-efficient buses and sizeable publicly or privately owned fleets of vehicles. They must work systematically and internationally towards requirements of energy efficiency of vehicles, standards for electric cars, new fuel technologies and knowledge-sharing.

Germany

There are many cities in Germany like Munich and Frankfurt emerging as a bicycle-friendly transport network. Both the cities are well developed with a comprehensive mass transit system dominated by underground metro system coupled with the light rail transit (LRT) system.

New York, USA

There are major differences between cities; an average US urban dweller consumes 24 times more transport energy annually for private transport than a Chinese urban resident, and almost four times as much as a European urban dweller. These differences cannot be explained by wealth alone but are closely linked to the rates of walking, cycling and public transport use and to enduring features of the city including urban density and design.

Cities and nations that have invested most heavily in car-based transport systems are now the least environmentally sustainable, as measured by per capita fossil fuel use. The social and economic sustainability of car-based urban planning has also been questioned. Within the US, residents of sprawling cities make more frequent and longer car trips, while residents of traditional urban neighbourhoods make a similar number of trips, but travel shorter distances and walk, cycle and use transit more often. It has been calculated that New York residents save US$ 19 billion each year simply by owning fewer cars and driving less than the average American as the residents use public transport to a significant extent.

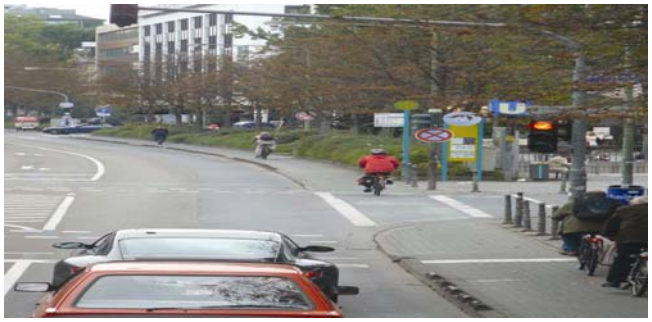

Figure 2. Bicycle network in Frankfurt.

Figure 3. Bicycle and LRT network in Frankfurt.

Impact of transport on environment

Transport system is responsible for both the positive and negative impacts on the society in which we live. The immediate concern of the ill effects of transport is generally the high level of air pollution and traffic noise, which are both harmful to our health and degrade the environment. The following are some of the issues related to the impact of transport on environment.

Transport is a sector responsible for the greenhouse effect. According to WCN, UNEP and WWF[4], the change in climate induced by the addition of greenhouse gases to the atmosphere is one of the biggest threats to our society and sustainability. This greenhouse effect is a sequence of events whereby heat energy from the sun is trapped in the earth's atmosphere by ozone, water vapour and carbon dioxide. A large amount of carbon dioxide released due to fuel burning either by transport or industry/thermal power station or every other means could result in the gradual warming of the earth's atmosphere. Joseph Fourier was the first person to discover the greenhouse effect. Greenhouse effect has a tremendous negative impact on our society. These include the effect/melting of most of the polar ice and rise in the sea level; which would ultimately pose a serious threat to our society and result in the following situations.

- Displace populations.
- Destroy low-lying urban infrastructure.
- Inundate arable land.
- Contaminate freshwater and a use recession of shorelines and wetlands.
- Increase tidal ranges.
- Spread diseases such as malaria, schistosomiasis, leishmaniasis, dengue and Japanese encephalitis.

Among the various gases, carbon dioxide, methane and nitrous oxide generated by vehicular traffic and chlorofluorocarbons (CFCs) are the primary greenhouse gases contributing to global warming with a share of 55%, 15%, 6% and 17% respectively.

Air pollution

As discussed earlier, the transport sector is one of the key areas responsible for a large-scale generation of air pollution. Table 1 presents the contribution of various air pollutants due to transportation to the total air pollution[5].

The rapid increase of vehicular traffic on the roads in Delhi poses a major pollution threat to Delhi. The daily emission of vehicular pollutants has increased to a considerable extent. The pollution load from petrol-driven vehicles is higher than that of diesel vehicles. The major pollutants are CO, HC, SO_2 and NO_2. Besides these, ozone concentration is exhibiting an increasing trend. High concentration of ozone in the winter period has been recorded in Delhi, with a maximum of over 600 μg per cubic meter according to a CRRI study[6].

Table 2 presents a comparative concentration of air pollutants in a few metropolitan cities. The effect of CO is serious, causing haemolysis of blood. Oxides of nitrogen and sulphur aggravate breathing problems and cause bronchitis. Suspended particulates and contents of lead are suspected to cause cancer and problems of blood circulation respectively. The National Standards prescribed are presented in Table 3.

Noise pollution

About 130 million people in OECD countries are exposed to unacceptable noise levels (greater than 65 dB (A)) during daytime[7]. Noise pollution caused by road traffic is one of the most serious problems. The generation of noise level in the road system depends on factors such as traffic intensity, speed, the type and condition of the vehicle, acceleration depending on the level of congestion and quality of roads. Continuous exposure to noise of high intensity has serious implications on human health and efficiency. People living near the railway track are also exposed to a high degree of noise pollution. The study carried out at a residential area of Chennai, 30 m from the railway track indicates that the maximum noise level is around 74 dB (A) for the movement of trains[8].

As far as air traffic noise is concerned, the severity of aircraft traffic noise seems to be less pronounced when compared to the other two sources of noise according to the study.

Table 1. Transportation's contribution to the total pollution (%)

	France	UK	Germany	OECD (Europe)
NO_2	76	49	65	60
CO	71	86	74	78
HC	60	32	53	50
SO_2	10	2	6	4

Source: OECD[5].

Table 2. Concentration of pollutants through gasoline-powered vehicles in metropolitan cities in India (in $\mu g/m^3$)

City	SO_2	NO_x	RSTM
Delhi	4	16	189
Kanpur	4	15	169
Vadodara	4	42	34
Chennai	4	13	189
Kolkata	4	34	55

Source: Air quality in major cities, CPCB, Delhi. Data collected during 8 am to 8 pm on April 2002.

Transport demand in India

Among the major modes of transport, there are a large number of vehicles driven by petroleum products such as cars, scooter/motorcycles, buses, trucks, etc. in India. Motor vehicles are the dominant source of all pollution in the major urban centres of India. In the recent past, especially during the past decade, vehicular growth and fuel demand have rapidly grown in the Indian road transport sector (Table 4). Motor vehicle population has grown about 15% during 1980–1990. Scooters/motorcycles registered the highest growth rate with 19.6% followed by goods vehicles with 10.9%.

Table 4 shows that if this growth trend continues, there would be about 423.6 million petroleum-driven vehicles in India. This would have a tremendous impact on our environment. The transport demand for selected cities in India (Table 5) reveals that metropolitan cities such as Kolkata, Mumbai, Delhi and Chennai would generate a travel demand of more than 10 million trips. The modal split in favour of rail transport in other Indian cities would not be more than 33%.

Energy and transport

Energy consumption in the transport sector is very high and accounts for nearly one-third of the total commercial energy in the country out of which 84% energy consumption is related to fossil fuels. It would be noteworthy to mention that the rate of growth of energy consumption in India in the last three decades has been faster than the rate of growth of the economy as can be seen in Table 6.

It can be mentioned that the bicycle is a better option as compared to some of the oil-based modes (Figure 1). It can be seen (Table 5) that the biggest metros, viz. Kolkata, Chennai and Delhi experienced significant travel demand of more than 169 lakhs trips daily in the year 2001 as compared to the other Indian cities.

Table 3. National standards for different pollutants

City (location)	Concentration ($\mu g/m^3$)			
	Sulphur dioxide (SO_2)	Nitrogen dioxide (NO_2)	Respirable suspended particulate matter	Carbon monoxide (CO)
National standard	80	80	100	2000

Table 4. Growth of vehicles 1951–1989 (in lakhs)

Vehicle type	1951	1961	1971	1981	1989	1990	2001 (estimated)
Buses	0.34	0.57	0.94	1.54	2.94	3.18	9.50
Cars/jeeps	1.59	3.09	6.82	11.17	24.81	27.41	33.00
Two-wheelers	0.27	0.89	5.76	25.28	106.17	126.98	346.50
Goods	–	–	–	–	11.97	1326	–
Others	0.56	2.09	5.12	13.73	21..04	22.47	78.50
Total	3.06	6.64	18.64	51.73	166.93	193.30	423.60

Source: Motor Transport Statistics of India, Ministry of Transport. (–) Data not available.

Table 5. Transport demand (in lakhs) for selected cities

City	Total daily passenger trips 1966–1967	Total daily passenger 1981	Total daily passenger trips 2001 (estimated)
Kolkata	35	114.8	188.9
Mumbai	46.0	102.5	189.5
Delhi	19.8	70.0	169.1
Chennai	16.0	51.4	92.0
Bangalore	–	33.8	107.6
Ahmedabad	–	29.0	63.4
Pune	–	17.8	30.6
Jaipur	–	9.2	28.0
Lucknow	–	9.1	12.5
Coimbatore	–	7.9	12.9
Chandigarh	–	1.5	11.5

Source: Ref. 12.

Environmentally sustainable transport

There is no doubt that any transport system is the lifeline for any development in the society irrespective of social, economical, political and cultural aspects and virtually acts as an important catalyst to overcome any physical barrier. It is a well-established fact that the transport system and economic development go hand-in-hand with each other. Finally, the question arises as to what extent and what form of transport would be essential which would become an environment friendly sustainable transport system. This would ultimately reflect the minimum ill effect on the environment. In view of the problems of many cities in the world, the time is opportune to rationally evolve strategies on the selection of appropriate transport mode in our society. Owing to energy requirements, environment friendly concept, possible consequences of energy scarcity of oil-based transport and damages caused by it on the environment, a scale of environmentally sustainable transport system in the urban scale may be built and examined for its suitability.

Environment-friendly transport

Owing to the importance of the prevailing modes of transport and its impact on the environment, the following modes can be examined which could be of great significance for the creation of sustainable environment (Table 7).

The bicycle, the lowest order of environment-friendly vehicles, offers a reliable means of transportation. It is an economical, recreational, non-congesting and non-polluting means of movement. Additionally it can be used for physical fitness. For a trip length of 5 km, this mode may be ideal for urban areas. A comparison of the bicycle with other modes of petrol-driven vehicles is presented in Table 5. Cycle-rickshaw can be considered to play its role as intermediate or hired mode of transport even in future. For small- and medium-sized cities, the role of cycle-rickshaw should be given due importance. Even in metropolitan cities where mass transportation is not well developed, the cycle-rickshaw can be assumed to play a major role.

Table 6. Economic growth and energy consumption

Plan	Average growth rate of economy (% annum compound)	Average growth rate of energy consumption (% per annum)	Share of energy (% in the Five Year Plan)
First Plan (1951–1956)	3.5	9.6	19.7
Second Plan (1956–1961)	4.1	10.6	12.4
Third Plan (1961-66)	2.6	12.2	18.5
Fourth Plan (1969–1974)	3.5	6.3	21.2
Fifth Plan (1974–1978)	4.5	8.1	25.2
Sixth Plan (1979–1983)	4.7	11.1	28.2
Eighth Plan ((1992–1997)	6.8	–	26.5
Ninth Plan (1997–2002)	6.5	–	–

Source: Planning Commission, Government of India.

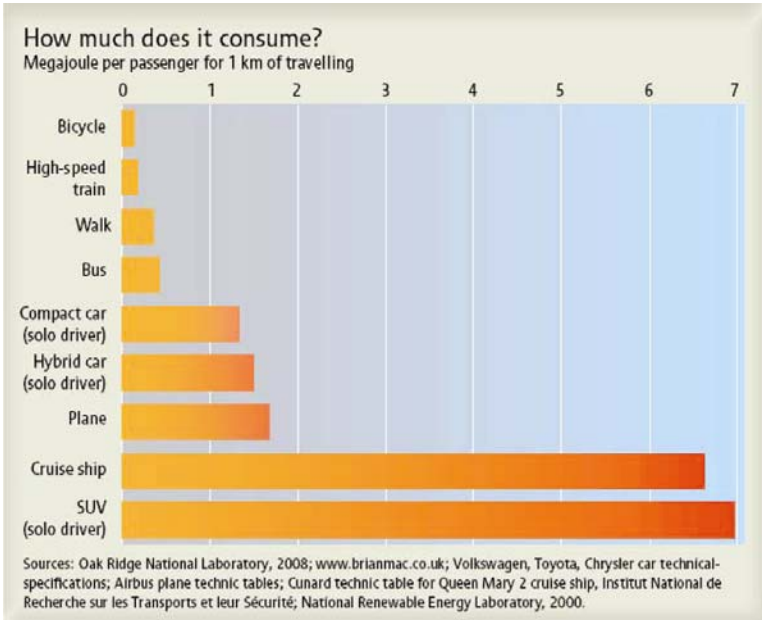

Figure 4. Energy consumption per km of travel by modes of transport.

Table 7. Personalized and mass transit modes for sustainable transport system

Bicycles	Personalized vehicle
Cycle-rickshaw	
Battery-powered vehicle	
Solar-powered vehicle	
Trolley bus, CNG-operated bus	Mass transport
Tram	
Light-rail transit	
Metro	

Battery-powered vehicles are on the road in certain places in Delhi. Major disadvantages of this type of vehicles is the heavy dead load as compared to the total weight of the vehicle and the low-intensity of electric charge. Research and development is presently on full swing in developed countries to find its commercial application. It is believed that this type of vehicle would be in greater demand in the near future, which would replace the prevailing personalized gasoline-driven vehicles.

Solar-powered vehicles are yet to find commercial success due to some limitations.

Trolley buses have also made a substantial impact in many countries in general and Nepal in particular. This system can be explored to replace the existing diesel-driven buses. Subsequently, the role of CNG-operated buses should be considered seriously as one of the environment-friendly modes of transport. Trams can play an important role in the overall transport system. The advantages of introducing trams as a major mode of mass transport are that they can move either on the street with the mixed traffic or on a reserved section of the street. A comparison of the tram with other form of mass transport is given in Table 9.

When there is a high travel demand in the travel corridor, it is appropriate to convert the conventional tram system into the modern LRT or Metro system. There are many countries in the world where the LRT system is becoming increasingly popular. Many cities such as Basel, Zurich, Karlsruhe, Strutgart, Nantes, Grenoble, Cologne

Table 8. A comparative assessment of the efficiency of bicycle with other modes

System parameters	Walk	Bicycle	Car	Bus
Speed (kmph)	6.4	16	16	16
Width of lane (m)	0.60	0.9	2.4	3.0
Capacity per lane	4,224	2,680	1,760	1,056
Number of lanes in 24 m road width	40	26.75	10	8
Total capacity	168,960	70,400	18,800	8,500

Source: Ref. 8.

Table 9. Transit system characteristics

System characteristics	Buses	Tram	LRT	Metro
Vehicle capacity	120	100–120	200–300	300–375
Vehicle per train	–	(1–2)	(3–6)	(4–10)
Lane/track capacity (passenger/h journey speed kmph)	16,000	20,000	25,000	70,000
Journey speed kmph	(15–30)	(10–25)	(15–25)	(30–35)

Source: Urban transit system guidelines for examining options by Alan Armstrong–Wright.

Figure 5. Unchecked traffic pollution.

and Hanover have experienced modernization and conversion from the conventional tram way network to the LRT system.

The last and costliest option is the Metro. Some of the developing countries are attempting to develop the Metro system which exists in London, Paris, New York, Chicago, Tokyo, Moscow and Toronto. In order to minimize the cost of construction, it would be worth considering locating the railway tracks at the ground level or above it. The system capacity could be enhanced to 80,000 passengers per hour per direction which is being considered for the Delhi Metro System.

Sustainable intermediate and public transport

Why do we need sustainable transport in Kolkata?

- Around 70% of Kolkata's 18 million inhabitants suffer from respiratory problems such as asthma and lung cancer, which are caused by pollution from the city's chaotic transport sector[9].

Figure 6. Plastic pollution.

- Noise pollution mainly from buses and autorickshaws causes some percentage of permanent damage to hearing, other than being a regular disturbance to work and studies.
- Growth in the demand for mobility and motorized transport is the single largest source of greenhouse gases and fast growing.

Table 10. Comparison between different transport systems of Kolkata

Type of transport	Positive points	Negative points	Solution
Tram	1. Does not use any form of fossil fuel, thus greenhouse emission is zero. Runs solely on electricity. 2. Low noise pollution as compared to other modes. 3. Low rate of accidents as trams travel on fixed tracks. 	1. Usage of a large amount of electricity. An alternate renewable source of energy could be thought of. 2. The sordid state of tram system is unreliable, and daily commuters prefer using other modes. 3. Trams carry less than one-fourth of passengers that they are designed to carry.	1. A comprehensive modern tram (LRT) network on reserved right way. 2. Increase the number of trams, with line haul and feeder routes through industrial and service zones.
Metro	1. Fixed tracks, no traffic congestion. 2. Fixed routes, thus creating a secondary efficient dependent transport system of cycle rickshaws and auto rickshaws. 3. Fastest way of connecting the north–south corridor in the city. 	1. Immense amount of noise pollution in closed tunnels. 2. Frequent lapse of security causing deaths. 3. Current supply is far less than the demand, thus causing rush hour crowd. 	1. Increase the number of trains. 2. Replace 20-year-old machinery with new ones, lessen noise pollution.
Circular railways	1. By far, the easiest way of travelling along the river Hooghly on the east bank. 2. Designed in the British era, it has major interchanges with tram and metro lines. 3. Cheap and fast mode.	1. Highly underutilized, the trains run for more of a social and cultural obligation than for utility. 2. Immense amount of industrial pollution on either side repels commuters. 3. Shanties on either side of tracks create unhygienic conditions.	1. It is not only the responsibility of the transport department, the urban planner should also find solutions to shift slums.
Suburban railways	1. Most efficient mode of transport for 2.5 million daily commuters from the suburbs. 2. Converges at Sealdah and Howrah, the two major stations. 	1. The old tracks are overutilized causing frequent derailments. 2. Overcrowding occurs, demand is more than supply, security is low. 3. Excess pressure on Sealdah and Howrah. 4. Pollution occurs in forms of illegal settlements along the tracks.	1. Increase the number of coaches on each train. 2. Increase the number of tracks. 3. Create a new station in the far south (Garia, for example) which is as important as Sealdah/Howrah.

(*Contd*)

Table 10. (*Contd*)

Type of transport	Positive points	Negative points	Solution
Water transport	1. No congestion as Hooghly river is wide enough to accommodate more than the required number of vessels. 2. Faster and cheaper than road transport across the river. 	1. Low marketing results in lower commuters. 2. Lack of secondary dependent communication systems from ferry ghats dissuade passengers. 3. A major source of water pollution as ferries do not use proper fuel, and often dump dirty oil in the river.	1. Use of LNG for the ferries. 2. Increase of ferry routes will pave the way for urbanized areas up the stream.
Buses	1. Connects urban, peri-urban and rural areas. 2. Efficient and cheap system. 	1. Highest emitter of greenhouse gases. Most buses use diesel and emit poisonous fumes causing health hazards and affecting longevity. 2. High in noise pollution, disturbs residential locality. 3. Poor conditions of buses cause frequent accidents.	1. Change to CNG buses. Few JnNURM buses have been introduced, more needed. 2. Change from private owners to government-owned.
Taxis	1. Connects all parts of the city. 	1. Not environment friendly, as it is almost as pollutive private vehicles. 2. Has approximately 1.1 passengers per trip, which is not acceptable. 3. Emits poisonous fumes, if unchecked.	1. Control the number of taxis plying. 2. Taxis have to ply at least a minimum distance, discouraging short distance trips.
Auto rickshaws	1. Fast and easy mode of communication. 	1. Very noisy, causes disturbance in residential areas. 2. Emits diesel fumes, very few autos run on CNG or LPG. 3. Problems of taking more passengers than the designated ones.	1. Law should enforce use of LPG or CNG. 2. Restrictive design to prevent travel of undesignated number of passengers.
Cycle rickshaw, hand-pulled rickshaw	1. Non-polluting system of travel. 2. Saviour in times of floods in the city. 2. Provides employment to unskilled workers of Bengal, Bihar, Jharkhand and Orissa. 	1. Creates traffic congestion as they cannot compete with speedy motorized vehicles. 2. Some argue it stunts urbanization.	1. Fix specific routes for rickshaws. 2. Make only-rickshaw roads such that people are encouraged to use them.

Figure 7. Reliance on IPT.

- The more the number of flyovers, roads, tunnels and parking spaces are provided, the more the demand for them. By restraining the unchecked development, both the city and human lives will be saved from further destruction.
- Sustainable solutions will make the best use of the city's assets without depleting them.

What are the objectives of transport solutions in Kolkata as a whole?

Sustainable transport solutions are identified by their linkage to targets and objectives. Transport planning and investment must have a purpose which must be clearly identified and reflect the views of the residents. There is a general level of agreement that these targets and objectives should include the following.

- Reducing air pollution
- Reducing noise levels
- Increasing the space, security and comfort for pedestrians and cyclists
- Reducing the number of cars and lorries on the roads and increasing the proportion of journeys accomplished by walking and cycling
- Developing and improving those modes of transport that are zero pollution on the streets (e.g. tram)
- Establishing safe routes to schools, hospitals, workplaces, etc.
- Reducing road traffic accidents
- Reducing total energy consumption
- Increasing the amount of green space in urban areas
- Increasing the number of trees

About Kolkata

Kolkata is the core city within the Kolkata Metropolitan District. The major functions for the city of Kolkata are as follows.

- Trade
- Administration
- Manufacturing
- Service.

The city was founded as a trade centre in the late 17th century on the eastern bank of the river Hooghly, 160 km from the Bay of Bengal. It was the capital of British India. Today, it is the largest centre of finance, commerce and education in the eastern region.

Kolkata – Municipal Corporation area
Population – 4,580,544
Density of population – 24.76 per sq. km
Area – 185 sq. km
N–S direction – 18 km
E–W direction – 6 km

- Pollution is at its worst in Kolkata. The ideal count of suspended particulate matter (SPM) and respiratory particulate matter (RPM) should not exceed 140 and 60, respectively; but Kolkata's average SPM count is 211 and RPM count is 105.
- Over the past one year, only 20% of the city's 1.5 m registered vehicles reported for emission tests. The rest have been getting away spewing out deadly smoke.

The identified places where the maximum traffic pollution occurs are as follows.

- Important road traffic intersection junctions.
- Trade and commerce zones.
- Waterway ports.
- Taxi stands, auto stands, bus stands, where pollution is more in the form of garbage rather than emitted gases.
- Heavy vehicles such as lorries, buses and trucks ply on roads causing noise pollution.

In order to appreciate the various transport systems in Kolkata, Table 10 gives a quick glimpse of the positive and negative aspects of different transport systems with possible solutions to make them sustainable.

Conclusions

With a view to developing environment-friendly urban transport system, it is necessary to develop strong national transport policies where attempts should be made to discourage the prevailing petrol–diesel-driven vehicles to encourage bicycle traffic for short distances and to

promote battery-driven and solar-powered vehicles. In order to develop proper national transport policies, a critical evaluation of the present transport system with respect to the role of future transport system based on non-petrol and diesel-driven vehicles should provide a step further in this context. In this paper, the role of CNG-operated buses has been discussed in countries such as New Zealand, Argentina and Chile. For a country such as India, its feasibility needs comprehensive review, analysis and experimentation and application with improved technology. This analysis will receive an impetus from the fact that the public transport system in Delhi is now currently running on CNG. The planning for public transportation is an important exercise, which has a tremendous bearing on national development. Future transport policies should also be directed towards developing mass transport infrastructure based on an electrically-operated system that will have least impact on polluting the environment. The possible future mass transport scenario in our country may emerge into environmentally sustainable transport and may be primarily developed in the form of trams, trolley buses, battery-operated buses, LRT and Metro according to the prevailing socio-economic conditions of the cities. Sustainable transport policies have their greatest impact at the city level. Outside Western Europe, cities which have consistently included sustainability as a key consideration in transport and land-use planning include Curitiba, Brazil, Bogota, Colombia Portland, Oregon and Vancouver. Many other cities throughout the world have recognized the need to link sustainability and transport policies, for example by joining cities for climate protection.

In view of the existing transport scenario in Kolkata, it is necessary to convert diesel-operated taxis, trucks, buses and autorickshaws to CNG-based system immediately as in Delhi. Trams should to be rejuvenated and transformed to the LRT system which is more efficient with respect to speed and acceleration and deceleration power. An attempt should be made to optimize the potential of the existing inland water transport (IWT) system so that a sizeable transport demand made by other modes of transport can be reduced with the help of strengthening IWT in terms of increasing more routes and frequency of the services. A detailed feasibility study is needed in terms of reorganization and integration of transport systems as highlighted for achieving a sustainable transport system in Kolkata.

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