# URBAN TRANSPORTATION
## Challenges and Way Forward

*Infrastructure*


*Multi-modal Transport System*

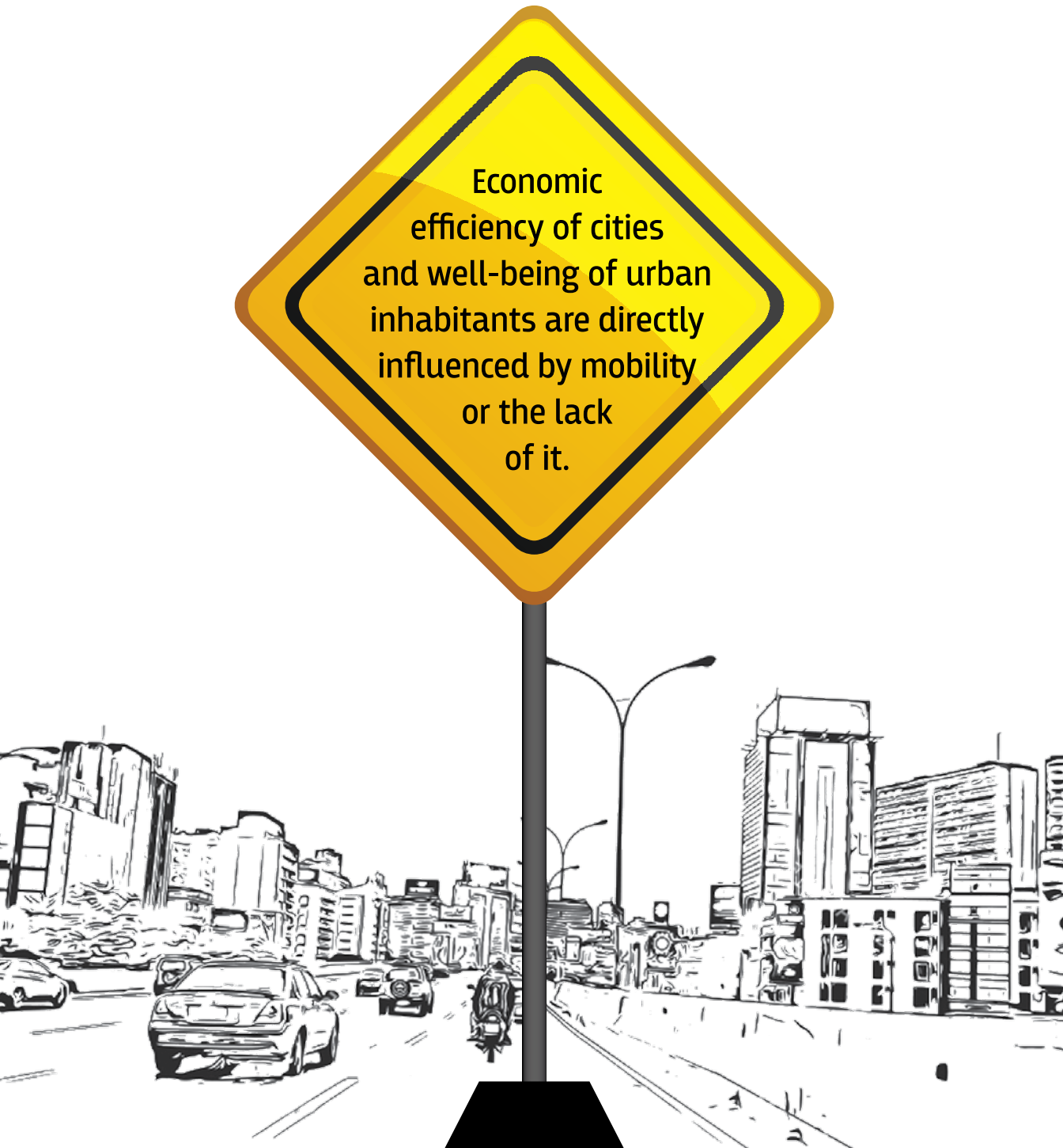
*Intelligent Transport System*

*Advanced Parking Management System*

INDIAN NATIONAL ACADEMY OF ENGINEERING
तमसो मा ज्योतिर्गमय
ESTD - 1987

A Report by

**INAE Forum on Civil Infrastructure**


Economic
efficiency of cities
and well-being of urban
inhabitants are directly
influenced by mobility
or the lack
of it.

# FOREWORD

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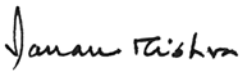
Indian National Academy of Engineering, established in 1987, currently has 834 Fellows, 81 Foreign Fellows and 118 Young Associates, who are amongst the most eminent engineers, having a marked track record of achievements. Over the years, consistent with its mission, the Academy has made significant contributions in developing India. It has recognised and honoured individuals with outstanding achievements, and, encouraged excellence by awarding worthy projects amongst students and young engineers. Another very important endeavour of the Academy has been to address engineering challenges relevant to National development, through studies of the same, and, by thus recommending actionable solutions. Towards this end, the INAE has set up Committees and Forums, consisting of domain experts from amongst the fellowship or even from outside. Thus, currently there are forums on such issues as, Indian Landscape of Advanced Structural Materials, Engineering Interventions for Disaster Management, Engineering Education, Energy, besides the one on Civil Infrastructure. The latter having been established in January, 2019.

Civil Infrastructure touches the lives of millions, and thus the reduction or removal of its deficiencies create an enormous challenge. The Forum thus set up to address this aspect of National development had proposed to study the subjects of Traffic & Transportation, Housing and Water. The Forum first

chose to work on Urban Transportation. The report arising out of the said exercise has been produced by authors with considerable experience and expertise, in the subject domain. The report contains an analysis of the challenges faced and their possible solutions, and, contains a set of actionable - recommendations. It is noteworthy that before its finalisation the draft was discussed at a Brainstorming Workshop, where a wide cross section of stakeholders participated and provided invaluable comments and suggestions.

Prof. Prem Krishna and his colleagues, who have authored this report “URBAN TRANSPORTATION – Challenges & Way Forward”, have put in substantial effort and done a commendable job in bringing out this volume, which has the promise to take Urban Transportation on a course of modernisation, and more efficient, convenient and safer city traffic. I place on record my compliments for their effort.



**Dr. Sanak Mishra**
**President INAE**

# PREFACE

URBAN TRANSPORTATION – Challenges & Way Forward, is a natural follow up of the INAE document, "Vision, Mission, and Values 2037", which was prepared in order to envision the future engineering scenario of the country and to draw up a road map of future activities of the INAE. It is easy to see that Civil Infrastructure, being a major concern for National development, emerged as one of the important areas to be addressed. Upon a proposal by the undersigned, the Academy set up a Forum on Civil Infrastructure, in January 2018, with a membership of domain experts drawn from the INAE as well as outside. The proposal had envisaged that it will study three areas of concern, namely, Traffic & Transportation, Housing and Water, in that sequence. This document marks the completion of the study of first of these areas.

The woes of City Traffic & Transportation have been in focus for last several decades, and, have continued to worsen. The cost to the Nation arising out of the related deficiencies is high. Clearly, the problem is complex and there are no easy solutions. The first task undertaken therefore was to put together relevant data and information and to identify the challenges. The report then follows with suggesting how the different parameters of the problem can be addressed to make Urban Transportation safer and more convenient with due usage of modern technology, and, improved organisation and policies. On this basis, the document has made a series of actionable recommendations.

The colleagues from the Forum, namely, Prof. Mahesh Tandon, Dr. Mangu Singh, Prof. N. Raghavan, Prof. P. K. Sikdar, and, Prof. Satish Chandra who joined the undersigned in preparing this document are all domain experts of this subject area. Furthermore, significant support was received from Dr. Madhu Errampalli, Senior Principal Scientist, CSIR-Central Road Research Institute (CRRI), in this effort. It was a pleasure and a privilege associating with them and the undersigned herewith records his appreciation of all these colleagues for their effort and support. A draft of the report was prepared based on the deliberations amongst the authors through a series of meetings, and back-up effort. Before finalising the report, its features were presented to a group of invited stakeholders at a Brainstorming workshop (see brief description in Annexure) held at the Metro Bhawan, New Delhi, on 10th July, 2019, and, its deliberations have been duly accounted for.

Last but not the least, the undersigned wishes to place on record the support received from Late Brig. Rajan Minocha and his team at the INAE office, particularly Mrs. Pratigya Laur, who helped in coordinating this activity.

**Dr. Prem Krishna**
Chairman,
Forum on Civil Infrastructure

Gurgaon,
28 August, 2019

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# EXECUTIVE SUMMARY

The INAE document on *VISION, MISSION & VALUES*, 2037, brings out the fact that, areas such as *Engineering Education, Energy, Infrastructure* (with its various aspects), take centre stage, and will continue to do so for National development. The subject area of *INFRASTRUCTURE* would deem to include Traffic & Transportation; Housing; different aspects of Water; Energy; and so on. The INAE set up a new forum on *CIVIL INFRASTRUCTURE* in January 2018 to study the areas of *Traffic & Transportation*, Housing, and, Water. To begin with, the Forum has addressed the issue of Traffic & Transportation.

It emerged from the initial deliberations that the woes related to intra-city *Traffic and Transportation* are not just due to any one or two issues, but have many dimensions – managerial, technical, societal, educational, and so on. Thus, it becomes obvious that if our cities have to become more comfortable to live in, a holistic approach will have to be followed considering all aspects of *Traffic and Transportation*. Out-of-the-box thinking, some hard decisions, and use of e-technology would seem imperative. It is only then that an efficient, sustainable, and, safe system will emerge for *Traffic and Transportation* in urban India.

Considering that the medium to large size cities were the worst sufferers from the *Traffic and Transportation* problems, it was decided to concentrate attention upon them. It is obvious that the application of ITS (Intelligent Transportation System) will need to be brought into effect as soon as practically feasible. Further, the absolutely necessary choice is to develop integrated multi-modal transportation systems, with due encouragement being provided for pedestrian and bicycle traffic, and to reduce the use of private cars. Another area requiring urgent attention is that of traffic control and management in order to bring in some sanity into the scenario. This will require to address the training and education of drivers, issue of licenses, and awareness amongst the users of the system through a 'media blitz'. For developing the civil amenities required for a city, it is a necessity that flexibility is provided in the norms and specifications to find solutions for given specific situations, rather than imposing uniform road design norms for urban and non-urban/ highway road networks alike. Technologies employed for construction may also need to be situation specific.

In view of the above backdrop, the first step was to make a study of the nature and dimension of the problem of city traffic. The broad terms under which this was assessed were, sizes of the cities and the nature of the problems, transportation systems deployed in a city and the related shortcomings, road safety scenario, and, an estimate of losses in economic terms on account of deficiencies of the system. It emerged that, the rapid pace of urbanisation would result in approximately 40% of the Indian population residing in cities by 2030. The trend is irreversible considering the present state of the villages and the amenities and opportunities offered by cities in comparison. According to the 2011 census, there were 53 cities in India with more than one million population and 7935 with more than a lac. The modal share of public transport should ideally be between about 60 to 85 %, increasing with the population of a city. However, the current shares are less by almost 35-40%, which implies an unduly greater share of private cars and two-wheelers. Inadequacies of the road network

(since 2000, while road network in the country has grown by 39%, the number of registered vehicles has grown by about 158%), inadequate parking space and inappropriate parking habits, lead to congestion, pollution, accidents and delays. As per the published data by the MoRTH, Government of India, about 1,48,000 people died in road acccidents in 2017, with the major share being that from vulnerable road users (pedestrians, bicyclists and two-wheelers).

Traditionally, there has been a multiplicity of governmental or other agencies involved in the process of planning and development of transportation facilities, control of traffic and parking, regulation of different modes of travel, issue of driving licenses, and so on. This persists despite enormous changes in the demand side, as well as the greater availability of transportation facilities, even though these are not quite keeping pace with the demand. There is a dire need for out-of-the-box thinking in this respect, in order to bring in a greater centrality in handling the various aspects of Urban Transportation, and to introduce the required policy changes accordingly.

Furthermore, in a similar manner as above, the transportation infrastructure is driven by laws and specifications, often unmindful of the changing needs and technology, and lacking in imagination. This is another area requiring immediate focus.

These, in real terms are the root causes of city traffic woes. Considering both direct and indirect causes, an estimate of cost to the Nation on account of inadequacies in transportation facilities in medium to large cities is, of the order of, and more than ₹ 1.5 lac crore per annum.

On the positive side though, the system is duly recognising the onset of e-technologies for various functions of data acquisition and utilisation, as well as in traffic control, though this is happening rather slowly. As an example there are a few success stories - parking arrangements at Palika Bazaar, and Capitol Point, Connaught Place, South Square MLCP Sarojini Nagar, and at Delhi High Court; Advance Public Transport Information System such as Mysore ITS (MITRA); Intelligent Transit Management System, such as at Surat and Rajkot; Bus Rapid Transit System (BRTS) at Ahmedabad, and a successful metro rail system in the NCR.

Likewise, the recent developments and new ideas for improved urban transportation, such as, the use of elevated road networks or cable car networks, use of electric vehicles including private vehicles and public/commercial vehicles, or autonomous cars, are already being considered and are being employed in varying degrees.

Features of the possible approach/solutions to tackle the various aspects of the problems related to urban Traffic & Transportation are discussed briefly in the following sections of this note.

## Engineering Issues for Infrastructure

In the urban environment, projects for Traffic and Transportation essentially relate to road network, rail-based systems and pedestrians. Accent on public transport, pedestrians and non-motorized vehicles are the keys to sustainability of such projects. Civil infrastructure in these projects may take the form of bridges, viaducts, flyovers, elevated roads, tunnels and underpasses. Each urban infrastructure project is unique with its own set of local conditions and constraints, and thus, the choice of a particular type of solutions, or combinations, thereof, are essentially to be case specific.

Flyovers are typically of small length often a mere 500m, serving the limiting purpose of spanning across isolated obstacles like a cross-road or junction, rail tracks and streams, and do help in reducing congestion in traffic. However, the acquisition of land is seldom easy possible in a built environment and can incur huge costs. Engineers have found an effective solution of

increasing the capacity of an existing road by utilising its central verge for locating the supports and creating an elevated highway or metro rail on the deck above. In some cities two-level transportation structures have been planted on the central verge to tap the full potential of this precious space.

Elevated structures for roads and metros connecting important destinations within the city can be several kilometers long with occasional down ramps and interchanges or metro stations located at selected points to facilitate traffic and transportation needs. The reason for infrequent adoption of long elevated structures relates to higher initial cost and the ignorance of environmental impact of such a structure. This arrangement is now being adopted increasingly, and may well become the norm rather than an exception.

While above ground and physical constraints can be visualized in advance, the location and identification of underground utilities criss-crossing below ground, and the effect on existing buildings in the vicinity, can pose serious problems. A complete digitisation of the records of utilities and structures within the city limits should be carried out and should be freely available to agencies involved in any construction project in the concerned area.

The norms for lane widths, clearances and loading that are used for designing expressways/ highways are not required to be imposed on the entire city network. These may be imposed only selectively if required in some major corridors of the network.

The city administration must involve competent professionals, right from the conceptual stage, in making all key decisions so that the shape and form of the facility can reach the levels of safety, security and sustainability that is concomitant with the attention, effort and expenditure on such projects.

Underground metro structures require enormous contiguous areas to be dug deep below the ground level while the connecting tunnels may have to traverse below existing buildings. Special expertise of Structural and Geotechnical Engineering requires to be mobilized to ensure safety of public and workmen in such situations.

A special requirement for structures in urban environment relates to safety not only during service but also during construction where significant number of accidents can take place when structures are in an incomplete stage.

While R&D related to technological aspect needs continued attention, it has to be remembered that the volume of Indian infrastructure demands is enormous, and requires to be addressed in relation to resources, and constructional materials as well. In this respect, due effort is needed to be invested on the utilization of re-cycled materials.

## Multi-Modal Transport System Development

Freedom for movement is an eternal need and the techno-social-economic revolution is driving transport demand in an unprecedented way, where distance is no longer considered to be a deterrent. It is understood that in future, the demand for travel will rise faster than population or average income or even the rate of GDP growth, just because of the pressure of urbanisation. The 2030 Agenda for Sustainable Development, adopted in 2015 by all United Nations Member States, are the 17 Sustainable Development Goals (SDGs), which call for urgent action by all countries - developed and developing - in a global partnership. As mentioned in the list of goals, the sustainable cities and communities and climate change are to be focussed in the long term transportation plans.

It is necessary to formulate an integrated transport policy to ensure adequate, efficient and high quality of transport services, which are safe to all in general and to children, women and elderly

people in particular. Planned development of multi-modal systems with integrated Intermediate Public Transport (IPT), Non-Motorised Transport (NMT) and pedestrian access facilities for all public transport modes available in the cities are the major challenges, where state governments can play the vital role. Implementation and functioning of Unified Metropolitan Transport Authority (UMTA) and Urban Transport Fund (UTF) for their true objectives can facilitate much needed institutional reform and integration in urban transport development. UMTA/UTF can formally plan for the multi-modal transport environment, duly exercising their unifying authority, and recognising multi-modality possible in different environment of urban space. The states have to enact and empower the UMTA to be in the saddle with complete legal backing. Furthermore, it is imperative that the Government of India consider legislation in the form of the Urban Transport Act to strengthen UMTA and its implementation in the states.

Information Technology (IT)/ Information and Communications Technology (ICT) applications can play a pivotal role in providing a multi-modal transport system through a central command and control centre for ensuring the quality and quantity of services in the system. The investment that will be required to develop the urban transport, as integrated multi-modal system, will pay for itself in a short time. The currently pursued philosophy of privatisation in transport sector can be used to achieve this in the shortest possible time, but must not be in a piece-meal approach and should be a guided development of multi-modal system. Thus, integrated multi-modal urban transport system in large cities can provide convenient, efficient, safe and environmentally benign urban transport. Moreover, a reliable IT enabled urban transport will ensure a smart growth of these cities.

## Parking Policy & Facilities

Some estimates indicate that, a car is parked for 95% of time, and thus the enormous demand for urban land for parking. The current scenario would point very strongly towards the inadequacy of parking spaces. Furthermore, ineptness of implementing whatever policy is available on paper leads to parking encroachment (in terms of on-street parking) on public spaces and walkways, compromising use of sustainable modes namely bicycles, pedestrians etc. The ultimate result is traffic congestion, accidents, unequal demand and supply ratio, and, environmental hazards etc. There is an urgent need to overcome the current situation by creating a systematic process of utilising IT and the modern approach of using basement and multi-level parking, automatic or semi-automatic systems, combined with stricter controls.

## Intelligent Transportation System

An Intelligent Transportation System (ITS) can address the issues of automated traffic coordination and multi-modal integration, real time information on traffic and guidelines to locate better traffic corridors, and, real-time information for passengers in public transport systems to facilitate free flow of traffic - time & cost savings, savings in man-hours, reduction of pollution (reduction of carbon footprint).

ITS has many facets and modes for making urban transport safe, efficient and attractive in operation. It can be implemented in modules in various areas or in a holistic manner in new urban developments or smart cities. This consists of such modes as, Electronic Toll Collection; Bus Control System; BRT Control System; Remotely Managed Traffic Signal Control System; Parking Space Identification and Facilitation System; Real Time Incident Warning System; Traffic Control System-advanced integrated multi-modal regulation system; traffic violation detection and punishment system, interceptor system; bicycle hire system for metro stations; Advance Traveller Information System (ATIS); Automated Variable Message Display Systems; Automatic Traffic Counter-cum-Classifier System; Vehicle Actuated Signals; multi-

modal route navigation for transportation system (for example Google Maps).

ITS is an advanced technology and is a collection of multi-disciplinary systems, which are in various stages of evolution. For instance, it covers Embedded Systems, Geographical Positioning System (GPS), General Packet Radio Service (GPRS) and Geographic Information System (GIS) technologies, Global System for Mobile (GSM) and mobile computing technologies, Signal Processing, image processing, real time and cloud-based computing, instrumentation and sensor technologies, wired and wireless networking, machine learning, statistics, transportation engineering, etc. Hence, ITS is a conglomerate technology and requires advanced research institutions to be involved in its implementation. ITS being an advanced technology comprising a host of hardware and software and requiring extensive deployment even for moderately large cities, is expensive and intricate for usage. Apart from political and bureaucratic backing it needs a carefully developed implementation strategy. The exact systems to be deployed, and the extents of usage will have to be determined after a thorough analysis of a city's problems, logistics and background.

Action required by various authorities in an integrated manner are, switch-over to standardised "smart" number plate system all over the country; National database on vehicle registration, active encouragement of Radio Frequency Identification Device (RFID) System for ETCS (Electronic Toll Collection System); National database on driving licenses; setting up Integrated Traffic Control Centres in cities; Expert Traffic & Transportation Systems; Automated and Integrated Fare collection systems; traffic violation citation systems based on automated violation detections; public education campaigns to utilise the ITS systems effectively.

The actual time required for implementing ITS systems would depend upon the extent and type of implementation and cannot be quantified easily a priori. Considerable time would be required in the beginning for planning and for identifying specific systems, and later for procurement of relevant hardware and software, recruitment and training of expert personnel, public education campaigns, installation of the systems on the ground, testing and commissioning finally leading to operations phase. The intervening time would certainly be in the range of a few years, possibly 2 to 5 years, depending on the complexity levels involved and the experience gained with progressive implementations.

## Public Education, Societal Involvement and Behavioural Modification Issues

Road safety campaigns based on appropriate measures covering the entire spectrum of causes for accidents and behavioural patterns of road users are required urgently. The road safety situation is governed by many factors: drivers and their driving skills and abilities; pedestrians and other road users (like NMT); state of the road ecosystem in terms of space as well as organisation of space, geometrics, quality, lighting, signalling, etc., state of the vehicles using the roads, etc. Any road safety improvement campaign must address all these factors and should be based on a good understanding of the dynamics of accidents, the behavioural patterns of the people involved, the limitations of the infrastructure, etc. Fortunately, in the recent past there is a growing interest in studying behavioural counter measures, and leveraging measures centered on changing human behaviour through education and publicity.

## Areas recommended for attention

Keeping in view the coverage in the various sections of this report dealing with different

aspects of Urban Transportation, the issues requiring attention are identified under four heads, namely, Organisational Issues, Policy Issues, Intelligent Transportation Systems (ITS) Issues and Engineering Issues. It is noteworthy that during the few years immediately preceding the study being reported, some of what is being recommended has been attempted in the country with a reasonable degree of success. However, this has happened in a very limited way, and there is a need to cover much wider ground.

Thus, whereas clearly there are a few areas for which impetus has to be provided to come out of the 'as is' mode and for accelerating the pace of implementation, there are others for which action is to be initiated. The latter are grouped under Section 6.

### *Organisational Issues*

There is a clear need to avoid multiplicity of responsibility and controls in developing/ implementing various aspects of urban traffic & transportation systems. Whereas, broad policies have to emerge from the central government, the baton has then to pass on to the state governments and finally to rest with city administrations. Considering the vital importance of metro rail development for easing out the urban traffic problems, it is imperative this is provided with greater independence rather than being encumbered by the norms, practices and controls of the conventional railway systems. Similarly, other mass transport systems (high capacity modes) are also to be developed based on the projected corridor level travel demand in the cities.

Implementation and functioning of Unified Metropolitan Transport Authority (UMTA) and Urban Transport Fund (UTF) for their true objectives can facilitate much needed institutional reform and integration in urban transport development. UMTA/UTF can formally plan for the multi-modal transport environment, duly exercising their unifying authority, and recognising multi-modality possible in different environment of urban space. The states have to enact and empower the UMTA to be in the saddle with complete legal backing. Further more, it is imperative that the Government of India consider legislation in the form of an Urban Transport Act to strengthen UMTA and its implementation in the states.

An all-India cadre should be set up consisting of Traffic & Transportation personnel, including ITS experts in various fields (planning, IT, utilities, mechanical systems, etc.) for faster and more efficient delivery. There is an increasing need to deal with enforcement issues and the Law & Order machinery should be strengthened and modernized to take care of this effectively.

### *Policy Issues*

National-level policies, to drive the multi – modal transport environment, will have to be framed for promoting and implementing integrated public transportation systems such as metros, BRT, with special provisions for NMT (bi-cycles and pedestrians etc.) for various urban centres in a planned manner expeditiously. Likewise, a policy framework is needed to set up a national database of all motorised vehicles covering smart number plates and all driving licenses by adopting smart card driving licenses, etc. and real time traffic accident data for capture and management. Policy is also to be evolved for introducing greater automation and follow an on-line approach for parking facilitation and for issue of driving licenses as well as issuing challans.

### *Intelligent Transportation Systems (ITS) Issues*

Technologies should be developed and implemented in a planned, integrated manner across urban centres, using standardised techniques and systems across India to share knowledge, experience and costs, starting with stand-alone systems which can start yielding results quickly, after due public education

campaigns. This can be followed up with efforts towards wider use and networking with automation to be introduced into Toll Collection, Traffic Control Systems including detection of traffic offences and issue of challans. Universal contactless smart cards valid across all public transport systems should be utilised for fare payment. Likewise, Integrated Information Systems or City Traffic App for multi-modal transport system in a city, giving map-based information for transit from point A to point B across all available systems, including IPT systems, should be developed.

### *Engineering Issues for Infrastructure*

Urban structures catering to traffic shall be planned, designed and constructed, employing Professional Engineers (PE) to ensure safety and sustainability with an eye on aesthetics, rapid construction with maximum possible pre-fabrication, minimum disturbance to underground services (after their detection using all available geotechnical and geophysical methods) and existing traffic. IRC codes should permit necessary deviations in geometrics and loading standards to be applied judiciously for urban situations, which call for it.

Further, in order to facilitate appropriate planning of infrastructure for Urban Transportation, it is imperative that the space in cities, both above and below ground, is surveyed and accurately mapped in the digital mode, to be available to planners and the engineering organisations.

## The Way Forward

It is envisaged that the report and the areas identified for attention will be assessed by an appropriate body of the Government of India and be shared with the State Governments, who will be involved in a major way in implementing the actionable recommendations. On the basis of Section 5, it is recommended that action be initiated on the following aspects related to Urban Transportation;

1. An all-India cadre should be set up consisting of Traffic & Transportation personnel, including ITS experts in various fields (planning, IT, utilities, mechanical systems, etc.) for faster and more efficient delivery.
2. Considering the vital importance of metro rail development for easing out the urban traffic problems, it is imperative this is provided with greater independence rather than being encumbered by the norms, practices and controls of the conventional railway systems.
3. National-level policies, to drive the multi-modal transport environment, will have to be framed for promoting and implementing integrated public transportation systems such as metros and BRT, with special provisions for NMT (bi-cycles and pedestrians etc.) for various urban centres in a planned manner expeditiously.
4. A policy be framed to enable the setting up of a national database of all motorised vehicles covering smart number plates and all driving licenses adopting smart card driving licenses, etc. and real time traffic accident data capture and management.
5. Automation to be introduced into Toll Collection, Traffic Control Systems including detection of traffic offences and issue of challans, besides the development of a City Traffic App for multi-modal transport system in a city, giving map-based information for transit from point A to point B across all available systems.
6. IRC codes should permit necessary deviations in geometrics and loading standards to be applied judiciously for urban situations, which call for it.
7. In order to facilitate appropriate planning infrastructure for Urban Transportation, it is imperative that the space in cities, both above and below ground, is surveyed and accurately mapped in the digital mode, to be available to planners and the engineering organisations.

8. Implementation and functioning of Unified Metropolitan Transport Authority (UMTA) and Urban Transport Fund (UTF) and integration in urban transport development. Furthermore, it is imperative that the Government of India consider for legislation in the form of the Urban Transport Act to strengthen UMTA and its implementation in the states.

9. A nationwide drive to improve safety on the road has to be taken up in a comprehensive manner, involving all the stakeholders, through appropriate media campaigns, etc. as the safety statistics are very alarming and getting worse day by day.

# INTRODUCTION

**Kochi metro bridge straddling** railway tracks at Erunakulam railway station with span arrangement 65m + 90m + 65m. Example of construction where difficulties imposed by physical constraints were successfully overcome.

# 1. INTRODUCTION

## 1.1. Background of the Forum

A new Forum on Civil Infrastructure was formed by the INAE as a follow up activity of the INAE VISION 2037, wherein the subject areas such as *Engineering Education, Energy, Infrastructure,* among others, have been brought into focus. The subject area of *Infrastructure* would deem to include Traffic & Transportation; Housing; different aspects of Water; Energy, as the main verticals. The proposal to set up this Forum had intended to cover *Traffic & Transportation, Housing and Water.*

INAE notified the formation of the Forum in July, 2017 to address the problem of *Traffic & Transportation* with the composition as follows: ***Chairman -*** Dr. Prem Krishna ***& Members -*** Prof. Mahesh C. Tandon, Dr. Mangu Singh, Prof. P.K. Sikdar and Dr. Kumar N. Sivarajan. The discussions in first meeting, pointed to the enormity of the task in hand. It was decided to request the President of INAE to strengthen the group with the addition of more experts. Such a request by the Forum was acceded to by the INAE Council, and the experts added vide a notification in January 2018, were Prof. K. K. Ramamritham, FNAE, Prof. N. Raghavan, FNAE and Prof. Satish Chandra, Director CRRI.

It is noticeable that, despite the issues of urban transportation having been in focus for many years, the large & medium size cities of the country continue to face increasingly serious problems of *Traffic & Transportation*. Thus, first of all,a critical analysis of the efforts and results of the recent years was carried out. Based on the aforesaid review, and the deliberations of the Forum, this 'White Paper' has been prepared, which makes recommendations keeping in view such aspects as, developments in construction materials and technologies, evolving systems for traffic management and control, need for multi-modal transportation system, enhanced utilisation of online approach, inputs for education, training and awareness, and required policy intervention, to bring in a unified system for all issues related to Traffic & Transportation for cities.

## 1.2. Objectives and Scope

The main objective of the forum is to create from its study, a "White Paper" to provide a set of actions needed to lift substantially, the current Traffic & Transportation scenario in the cities, from its present state. Before finalisation, the draft report was put up for discussion amongst stakeholders in a workshop organized for this purpose.

## 1.3. Methodology Adopted

In studying this problem, the focus has been the Traffic & Transportation aspect, particularly in the large & medium size cities of the country. It was decided to first make a comprehensive study of the problem involving not only the engineering issues, but also other related ones such as, policy interventions needed, societal involvement, and regulatory mechanisms. A comprehensive note was prepared to identify major Traffic & Transportation problems. The notes addressed Travel Demand Management, Infrastructure in Urban Environment, Multi-Modal Transport & Reduction of Private Vehicles, Parking Policy for Urban Areas, Sustainable Transport Planning,

Intelligent Transport Systems, Modified and Unified Institutional Systems and Enforcement Issues, Public Education, Societal involvement and Behavioural Modification Issues. Based on this, effort has been made to identify a short list of implementable ideas along with strategies for putting these to practice.

# TRAFFIC AND TRANSPORTATION PROBLEMS

**Connecting satellite towns and sub-cities** Metro Lines are not only providing intracity connectivity but are also contributing in increased intercity mobility by connecting satellite towns like Noida, Ghaziabd, Gurugram, Faridabad and connecting them with subcities like Dwarka and Rohini in Delhi.

# 2. TRAFFIC AND TRANSPORTATION PROBLEMS

## 2.1. Growth of Urban Centers

Urbanisation is taking place at a fast rate in India. Population residing in urban areas, according to 1901 census, was 11.4%. This increased to 28.53% in 2001 and 31.2% in 2011. According to a 2007 survey by UN State of the World Population report, by 2030, 40.76% of country's population is expected to reside in urban areas. While the main reason for urbanisation in India is attributed to the eleventh five-year plan that aimed at urbanisation for the economic development of India, other reasons like economic opportunities, infrastructure facilities in the urban areas, growth of private sector after 1990 and growth of employment opportunities in cities are also responsible. As of 2011 census of India, there are 53 metropolitan cities (city with more than one million population) in India and the number of medium size cities with population of 0.1 million or above have increased from 5161 in 2001 to 7935 in 2011. The top ten metropolitan cities in terms of population (Census, 2011) are given in Table 2.1.

Economic efficiency of cities and well-being of urban inhabitants are directly influenced by mobility or the lack of it. City efficiency largely depends upon the effectiveness of its transport systems, that is, efficacy with which people and goods are moved throughout the city. Although

| Rank | City | Population |
|---|---|---|
| 1 | Mumbai | 18,414,288 |
| 2 | Delhi | 16,214,838 |
| 3 | Kolkata | 14,112,536 |
| 4 | Chennai | 8,696,010 |
| 5 | Bengaluru | 8,499,399 |
| 6 | Hyderabad | 7,749,334 |
| 7 | Ahmedabad | 6,352,254 |
| 8 | Pune | 5,049,968 |
| 9 | Surat | 4,585,367 |
| 10 | Jaipur | 3,073,350 |

**Table 2.1: Ten Most Populous Cities of India**

Indian cities have lower vehicle ownership rate than their counterparts in developed countries, they suffer from congestion, delay, pollution, and accidents.The main reason for all these is the prevailing imbalance in modal split besides inadequate transport infrastructure and its sub-optimal use. Public transport systems in cities have not been able to keep pace with the rapid and substantial increases in demand over the past decade or so. As a result, people have turned towards personalised modes such as two-wheelers and cars. Table 2.2 shows the present share and desirable share of public transport in cities of different sizes. However, in the last two decades or so, the share of public transport has decreased further.

| City Size (Population) | Present Share of Public Transport | Desirable Share of Public Transport |
|---|---|---|
| 1 - 2 million | 30% | 60% |
| 2 - 5 million | 45 - 50% | 75% |
| More than 5 million | 50 - 60% | 75 - 85% |

**Table 2.2: Modal Share in Different Indian Cities**

## 2.2. Transportation Systems Deficiencies

Transport systems are closely related to socio-economic changes. The mobility of people and freight and levels of accessibility are at the core of this relationship. Economic opportunities are likely to arise where transportation infrastructure is able to meet mobility needs and insure access to markets and resources. From the industrial revolution in the 19th century to globalisation and economic integration processes of the late 20th and early 21st centuries, different regions of the world have been affected differently by economic development. International, regional and local transportation systems alike have become fundamental components of economic activities. A growing share of the wealth is thus linked to trade and distribution. An inadequate or non-sustainable transportation system will hamper the economic growth of the nation. The negative consequences of inadequate transport are congestion, accidents and mobility gaps.

Transportation in urban areas is highly complex because of the modes involved, the multitude of origins and destinations, and the amount and variety of traffic. Traditionally, the focus of urban transportation has been on passengers as cities were viewed as locations of human interactions. However, cities are also locations of production, consumption and distribution, activities linked to movements of freight. Public transport, private transport and freight transport are therefore keys to any urban centre. Thus, besides commuting, leisure/ cultural activities and commercial transactions have lead to intricate traffic patterns. Inadequacy of public transport (road based or rail based) leads to rise in the number of personalised vehicles. Traffic composition at signal controlled intersections in a few metropolitan cities of India is shown in Table 2.3.

As may be seen from Table 2.3, the share of buses in all these cities is 2-7%. It has resulted in the ownership and use of large number of personalised vehicles like two-wheelers and cars, which has in turn increased the traffic volume on roads.

India is passing through the same phase of early urbanisation which has already occurred in countries like Japan, Republic of Korea, and Singapore. The per capita trip rate for all modes

| City | Traffic Volume (vehicle/day) | Average Traffic Composition % | | | | | |
|---|---|---|---|---|---|---|---|
| | | Cars | 2-Wheelers | Auto | Bus | Bicycle | Others |
| Delhi | 82,000 - 429,000 | 39.7 | 30.7 | 13.2 | 2.7 | 2.7 | 11.0 |
| Chennai | 60,000 - 160,000 | 26.0 | 54.1 | 10.2 | 3.1 | 2.0 | 4.6 |
| Chandigarh | 50,000 - 250,000 | 37.0 | 37.0 | 11.0 | 3.2 | 7.1 | 4.7 |
| Bhopal | 70,000 - 130,000 | 26.1 | 58.4 | 6.2 | 4.1 | 2.1 | 3.1 |
| Kolkata | 50,000 - 180,000 | 46.1 | 19.2 | 5.9 | 6.8 | 8.4 | 13.6 |

**Table 2.3: Traffic Data at Signal Controlled Intersections in Selected Cities of India**

[1] *Report on Public Transport in India by MOUD, 1998*

of transport was expected to increase from 0.8-1.55 in 2007 and is expected to become 1-2 by 2030 (Planning Commission, 2011)[2]. Moreover, the share of public transport is also expected to decrease as there is a likely decrease in the journey speed of public transport from 26-17 km/h to 8-6 km/h during the same period (Planning Commission, 2011).

Amongst the 53 reported million plus population cities in 2011-12, Delhi had the largest number of registered motor vehicles, followed by Bengaluru, Chennai, Hyderabad, Pune and Greater Mumbai. These six cities accounted for 43% of the total registered vehicles of the reported million plus cities. Srinagar reported the lowest number of registered motor vehicles amongst reported million plus cities in India. Amongst the top six cities in terms of the number of registered motor vehicles, the highest CAGR of 13.2% was recorded by Pune during 2002-2012, followed by Chennai (10.8%), Hyderabad (10.6%), Bengaluru (9.5%), Delhi (7.1%) and Greater Mumbai (6.6%) respectively. Other million plus cities like Kochi, Coimbatore, Madurai, Kanpur, Jaipur and Nagpur recorded more than 10% CAGR during 2002-12.

The average journey speed in Indian cities is also low, particularly in cities which have high car volumes (Ghate and Sundar, 2013). In 2007, a study commissioned for the Ministry of Urban Development, Government of India, found that the average journey speed in Delhi was around 16 km/h and only slightly higher in Mumbai. Increased traffic volumes on urban roads have made almost all the intersections completely saturated. Long queues and cycle failure are quite common during peak hours. This results in long delay and idling of vehicles at signalized intersections, fuel losses and emissions. Figure 2.1 shows the average percentage of vehicle idling at signal - controlled intersections in five cities of India (CRRI, 2017).

Similarly, in Mumbai, despite the fact that sub-urban rail link meets most of the suburban travel demand, road congestion is not reduced. During peak hours, traffic in Mumbai flows at a speed of

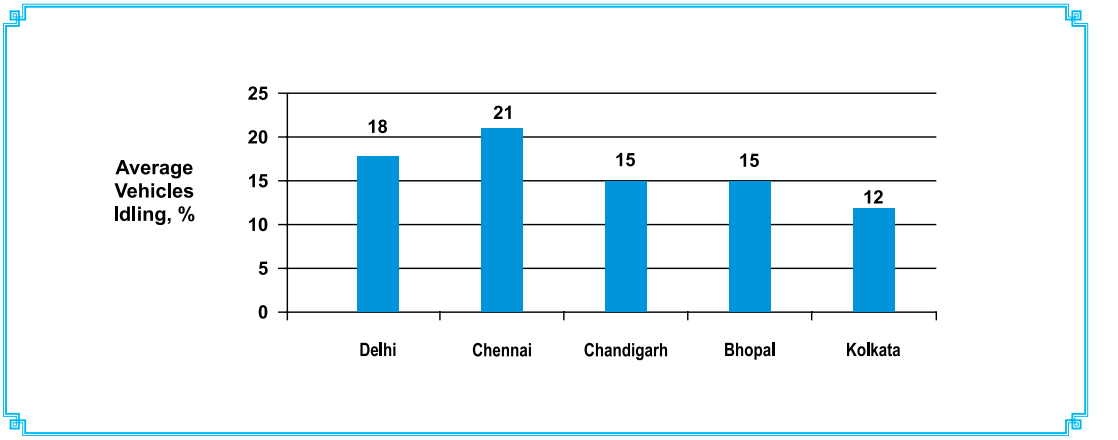



**Figure 2.1: Average Vehicles in Idling Conditions at Intersections**

[2]*Planning Commission (2011), Working Group on Urban Transport, Government of India, New Delhi, p. 28.*
[3]*Ghate, A. T. and S. Sundar (2013), Can We Reduce the Rate of Growth of Car Ownership ?, Economic and Political Weekly, Vol. 48, No. 23, pp. 32-40.*

5 km/h (The Economic Times, March 1, 2013). The total vehicles in Bengaluru and Hyderabad are around 6.8 million, of which around 70% are two-wheelers. On the other hand, cars and other passenger vehicles such as jeeps, taxis, and auto-rickshaws, account for around 25%, while buses account for only 0.7% of the total motorised vehicles registered in the cities of Hyderabad and Bengaluru. This indicates that there is a growing tendency of use of two-wheelers, cars, taxis and others in Indian cities.

## 2.3. Road Safety

With a surge in economy, vehicle population expanded in the country during the last couple of decades. Though road networks also improved, mounting pressure on roads from expanded vehicle population has aggravated safety issues. Absence of sustainable and adequate public transport system in cities has further worsened the situation. Since 2000, while road network in the country has grown by 39%, the number of registered vehicles has grown by about 158%. While growth in road network will be limited (due to physical constraints), a continuing increase in the number of vehicles on roads has led to congestion and road fatalities. Studies have shown that Bengaluru residents lose 600 million man-hours per year due to traffic congestion in roads, which accounts for ₹ 23.5 billion in monetary terms (Times of India, January 2017). As per the published data by the MoRTH, Government of India, 1,47,913 people died in road crashes in 2017.

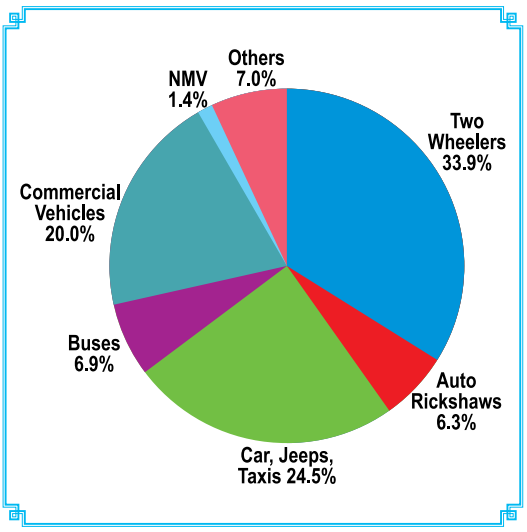



**Figure 2.2: Percentage of Accidents by Vehicle Type in 2017**

The annual report on Road Accidents in India released by the Ministry of Road Transport and Highways, records road accident data for cities with 50 million plus population. These cities accounted for 17.7% of the total road accidents in the country during 2017. City of Chennai leads with total of 7257 accidents followed by Delhi and Indore. The maximum deaths are recorded in Delhi followed by Chennai and Jaipur. Figure 2.2 shows the percent share in total accidents by vehicle type in the year 2017.

While the share of urban roads in total road network in the country is less than 10%, they constitute about 42% of total accidents and about 35% of fatalities. Table 2.4 gives the details of accidents data on urban and rural roads in 2017. About 38% of total accidents took place on the junctions during the calendar year 2017. The total loss to the nation due to road crashes is estimated to be around 3% of GDP, which is quite alarming.

## 2.4. Pollution and Health Impacts

Air pollution is one of the major environmental issues in most of the urban cities of India. Majority of the urban population is exposed to the poor air quality adversely affecting their health apart from various other adverse environmental consequences. Road transportation sector has been identified as one of the major contributors of urban air pollution. The problem of outdoor air pollution is quite serious in most of the cities in India where air pollution levels generally exceed

| Type of Area | Total Accidents | Persons Killed | Persons Injured |
|---|---|---|---|
| Urban Roads | 1,95,723 | 51,334 | 1,83,703 |
| | (42.1%) | (34.7%) | (39.0%) |
| Rural Roads | 2,69,187 | 96,579 | 2,87,272 |
| | (57.9%) | (65.3%) | (61.0%) |
| **Total** | **4,64,910** | **1,47,913** | **4,70,975** |

**Table 2.4: Accidents on Urban and Rural Roads (MoRTH, 2017)**

the air quality standards stipulated by Central Pollution Control Board (India). According to a recent WHO report (WHO, 2018), around 4.2 million people die every year worldwide due to outdoor air pollution. Further, among the world's 15 most polluted cities, 14 are in India (including Delhi). In fact, the air pollution has become the fifth largest killer in India with an estimated 1.5 million premature deaths per year due to air pollution related diseases.

In developing countries like India, cost, accessibility and convenience are the main reasons for extensive use of road-based transportation. Road-based transportation in India carry almost 90% of all passenger traffic and about 67% of freight traffic daily (MoRTH, 2018). There were about 230 million vehicles registered in India in the year 2016, growing at the average rate of about 9.9% per year. Among these, about 80% of the vehicles are personalised mode of transportation followed by about 10% public transportation (MoRTH, 2018). Presently, India's monthly diesel and petrol consumption is about 6.6 and 2.7 million tonnes respectively. With this monthly average consumption, it could be estimated that in the year 2018-19, India's total diesel and petrol consumptions would be around 79 and 28 million tonnes, respectively. Out of this total fuel consumed, road transport sector alone accounts for 70% of diesel and 99% of petrol consumption (PPAC, 2018).

Due to high demand of fossil fuels, transportation sector is the third most GHG emitting sector in India, in which the road transportation is the major contributor (Singh,et. al., 2018) at 94.5% and 53.3% of total annual $CO_2$ and CO transport emissions respectively (Ramachandra and Shwetmala, 2009).

The common air pollutants emitted through the motor vehicles exhaust include Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Sulphur Dioxide ($SO_2$), Unburned Hydrocarbons (HCs), particulate matter (PM2.5, PM10) and other organic compounds derived from combustion (Brugg, et. al., 2007). Further, over 70–80% of air pollution in India and other megacities in developing countries are attributed to vehicular emissions caused by a large number of older vehicles coupled with poor vehicle maintenance, inadequate road infrastructure and low fuel quality (Gulia,et. al., 2015).

India's urban population prefer to reside or work near/along the roads and highways, which makes them vulnerable to high pollutant concentration exposure due to the vehicles. Various studies

have reported that vehicle-related pollutants such as ultrafine particles, black carbon and CO are highly concentrated immediately downwind from the major trafficked road (Houstan, 2006 and Zhu,et. al., 2002). This endangers nearby populations and disproportionately exposes them to traffic-related air pollutants.

### *Increase in Vehicle Emissions*

The transport sector is responsible for approximately 25% of the total greenhouse gas emissions globally and is the fastest growing sector source worldwide. Between 2007 and 2030, global emissions from transport are expected to rise by 80%. Three quarters of the contribution is expected to come from road transport. Transport emissions are a major cause of climate change since excessive amount of carbon contributes to global warming. Urban transport emissions are likely to be especially problematic in the Asian cities due to growing city populations with rising incomes leading to higher demand for personalised motorized mobility, and the disproportionate climate change impact of short journeys due to inefficient engine use (Bannister, 2008).

Compared to a 2.1% increase per annum in greenhouse gas emissions from transport in the developed world, developing country emissions are expected to rise at a rate of 3.5% per annum upto 2030. As India and China race to catch up in economic growth, it will not be without climate change implications like the 2.5 tonnes of carbon emitted per head in Europe or 5.5 tonnes per capita emitted in the US, while the stabilisation targets worldwide are 0.5 tonnes, similar to that of India now. The scale of the challenge looks insurmountable.

The World Health Organisation (WHO) estimates that over 700,000 people die each year in South Asia as a result of ambient particulate matter pollution. In 2008, the CPCB identified around 70 cities, representing over 80% of the cities that were being monitored, that were not complying with the Nitrous Oxides ($N_2O$) and particulate matter (PM) standards. PM10 concentration in Delhi air increased from 120µg/m2 in 2001 to 250µg/m2 in 2010, where national standard is 60µg/m2 and WHO standard is 20µg/m2 (WHO Report, 2016). It has been shown that 22% of air pollution in Delhi is contributed by automobile emissions.

Recently, Government and other regulatory agencies have taken various measures to curb air pollution levels in various urban centres of the country (CPCB, 2015). Several measures have also been taken by the Government for reduction of vehicular pollution which includes introducing and enforcing the rules and regulations regarding the improved engine technology and lower emission norms for different categories of vehicles [Introduction of Bharat Stage (BS) Norms equivalent to EURO Norms], improved fuel quality, introduction of alternative fuels like CNG and LPG and, strengthening of public transportation system. Government of India has also decided to forgo (leap frogging) the BS V norms and directly implement the BS VI norms from 2020.

### *Trends in Air Pollution from Automobiles in India*

The automobile industry is one of the key drivers of the Indian economy, creating employment opportunities, improvement in productivity as well as facilitating the consumers in travelling and other day-to-day activities. Many passenger vehicles using petrol are now having diesel versions, which is much more polluting as compared to petrol version. As per some estimates, more than half the cars on the streets are going to be powered by diesel by 2020. Exposure to air pollution can lead to respiratory and cardiovascular diseases, which is estimated to be the cause for 620,000 early deaths in 2010, and the health cost of air

pollution in India has been assessed at 3 per cent of its GDP.

In recent years, air pollution has acquired critical dimensions and the air quality in most Indian cities that monitor outdoor air pollution fail to meet WHO guidelines for safe levels. The levels of PM 2.5 and PM10 (air-borne particles smaller than 2.5 micrometres in diameter and 10 micrometres in diameter) as well as concentration of dangerous carcinogenic substances such as Sulphur Dioxide ($SO_2$) and Nitrogen Dioxide ($NO_2$) have reached alarming proportions in most Indian cities, putting people at additional risk of respiratory diseases and other health problems.

### *Reasons for Air Pollution from Automobiles in India*

Some of the reasons for pollution from automobiles in India are as under:

- Absence of effective, efficient and well networked transport system in India
- Lack of fast railway network across India; which can run on cleaner technologies
- Lack of fast and cost effective intra-city railway network particularly in major cities
- Immense population in India with resultant huge number of vehicles in India
- Faulty traffic management systems and frequent jams
- No stringent enforcement of various standards/ norms for checking/curbing pollution
- Bad road conditions
- Adulterated fuels
- Older vehicles
- Inferior technology used in the automobiles
- Automobiles with faulty engines/equipment's or having bad maintenance etc.

In the recent past, National Green Tribunal (NGT) and Hon'ble Supreme Court of India have also given landmark judgments related to control of the vehicular pollution and improvement of urban air quality in India which include restriction/ban on old vehicles (10 years for diesel and 15 years for petrol driven vehicles in NCR). Further, NGT and Hon'ble Supreme Court of India have also issued several orders related to development and implementation of Graded Response Action Plan (GRAP) for Delhi and nearby regions (known as National Capital Region or NCR) as emergency response. In this GRAP, special emphasis has been given to control of emissions from vehicles which include banning of entry of heavy commercial vehicles in the city, maintenance of the smooth flow of traffic to avoid unnecessary idling, introduction of the odd-even policy of vehicles, heavy fine on polluting vehicles etc. (CPCB, 2017). In fact, recently the NGT has directed 23 states and union territories to form an Air Quality Monitoring Committee (AQMC) to prepare action plan on the lines of GRAP and other similar plans to bring the air quality standards within prescribed limits.

Efforts are also required to control the vehicular pollution at various "hot spots" like traffic intersections. Idling of vehicles at intersections results not only in the wastage of precious motor fuel but also causes deterioration of air quality due to idling emissions from these vehicles. Further, various traffic management and transportation planning measures need to be integrated towards control of vehicular emissions in the cities. From transport planning perspective, most influential aspect for reducing vehicular pollution is higher usage of public transport and non-motorized transport and to minimize the travel by personalised vehicles. This will lead to lower vehicular emission per person and lower congestion levels.

### *Measures to Tackle Air Pollution from Automobiles in India*

The emission norms (National Auto Fuel Policy) have helped in bringing down the pollution levels in India marginally, but the pollution levels

are rising across India in an unprecedented manner, particularly in the metro cities like Delhi. Therefore, stringent and drastic measures are required immediately like:

- Phasing out of old vehicles
- Ban on inferior technologies used in automobiles/engines like diesel etc.
- Well maintained automobiles with heavy penalty on the ones in bad shape
- Creation of effective and efficient transport system
- Fast and cost effective intra-city railway network e.g. Metro (MRTS)
- Implementation of sustainable public transportation systems and non-motorised transportation systems and their infrastructure
- Effective, fast and responsive traffic management systems avoiding jams
- Good road conditions with more flyovers and underpasses etc. Clean and good quality fuels like CNG
- Superior and environment friendly technology to be used in automobile production
- Stringent enforcement of various standards/ norms for checking/curbing pollution
- Faster implementation of the Bharat stage V and VI emission norms
- Curb on the number of vehicles in India by imposing heavy duties/ taxes
- Other measures like congestion tax, restricting entry/ using of vehicles etc.

## 2.5 Implementation Mechanisms for Metro Rail Development

The current system for planning transport systems in urban areas in India, places the responsibility for the same on the Transport Departments of respective State Governments. World-wide, the responsibility for the same is with the city Governments. Further, there is no unified approach in planning, incorporating all modes of transport, parking, etc., by any city Government. The problem is more severe in cities developed earlier without adequate control and regulations. The new townships and extension of the old cities however, are following some amount of control and regulations in the development. As per the Urban Transport Policy of Govt. of India, it is now mandatory to have unified transport authority for overall planning and control of the city transport system. Such authorities however are not formed in most of the cities and wherever formed, are not really functional. It is therefore, necessary that unified transport authority should be functional with adequate power to enforce its decision on the concerned Governments.

### *2.5.1. Technical Control on Metro Systems*

As per the Constitution of India, the Urban Transport comes under the Ministry of Union of India responsible for Urban Development. Similarly, the Railways come under the Ministry of Union of India dealing with Railways. It is causing a peculiar situation where metro transportation systems in cities are under dual control of Ministry of Urban Development (MoUD) and the Ministry of Railways. MoUD is responsible for planning, financing and overall coordination of the development and operation of the metro system, while the Ministry of Railways exercises the technical control.

The Rules of Business Allocation were made when there was no concept of metro system in our country and that is why the above situation has arisen. It is learnt that this dual control is causing impediments in development of the metro system in the country. Although metro technology

| Metro Experience | Railways Experience |
|---|---|
| Modern light weight (stainless steel or aluminium body) energy efficient coaches | Not a single such coach exits on Indian Railway |
| Modern signalling system ATP/ATO, CBTC type of signalling for high level of safety and capacity of the system | Not even a single km of such system exists on Indian Railway |
| Automatic Fare Collection System with contactless smart cards or token | Very little experience-Railway started this system in Kolkata Metro in year 2011 after the experience of DMRC |
| Tunnel ventilation and smoke-extraction system of underground tunnels and stations of international standards for life safety & evacuation of passengers | Railway has no experience of such systems |
| Metro systems need to negotiate sharp curves upto 120 m or even less and steep gradients upto 4% or more | Railway has very little experience in this field |
| Modern Ballastless Track | Railway has no experience in designing, laying and maintenance of such tracks |
| Rigid OHE for Traction | Not prevalent on IR |
| Platform Screen doors | Not existing on IR |

**Table 2.5: Metro and Railway Experiences**

is also rail based, it is far advanced and often different from the normal railway technology now available in the country. The Indian Railways do not have the domain expertise of modern Metro Rail systems or sub systems as can be seen in Table 2.5.

Metro technology is racing ahead in many areas to which railways have no exposure. Lack of metro experience and knowledge leads to delays in getting technical clearances. All metro administrations are therefore facing problem of delays in getting technical clearances from railway. The situation is further worsened as the Commissioner of Railway Safety insists on RDSO's or Railway Board's stamp on every technical matter. With such problems being faced by metro Rail Administrations there is total reluctance to bring in new innovations or technologies in metro constructions by which cost can be brought down and maintenance expenditure reduced.

The level III cities of the country, with less than 2 million population, will have to go for Light Metros with reduced axle loads, sharp curves upto 40 m radius and steep grades upto 6%. Railways or RDSO have no experience of such Light Metros and to obtain technical clearances from an agency which have no domain knowledge – and consequently lacking confidence in approving technical matters – will be a real uphill task.

Government is planning to make huge investments in metro systems in various cities across the country and the above situations therefore need to be changed. The following plan of action is therefore suggested.

- Necessary amendments to the Metro Act are to be made such that Central Government Ministry in relation to the Metro is Ministry of Urban Development and not Ministry of Railway (Railway Board).
- In the Ministry of Urban Development, a small technical cell consisting of metro experts may be created which will be responsible for technical and safety clearances of metros. This Cell may be funded by different metros in proportion to their sanctioned project costs.
- Commissioner of Metro Railway Safety should report to Ministry of Urban Development and all technical clearances will be given by Ministry of Urban Development through this dedicated technical cell. Necessary amendments to the Act will also be required for reporting of CMRS directly to Central Government (MoUD) and not through CCRS. There is no provision for CCRS in the Metro Act.

### *2.5.2. Managing the Technology*

At present procurements of rolling stock and systems for metros are being done on international global tendering system by respective metro Organisations. The technology is changing very fast, particularly, in the field of electronics, material and IT. For all these technological developments, country has to depend on the international agencies. R&D Centre for developing technologies is, therefore, in the interest of the nation. There are many issues which are unique to Indian conditions, for example, extreme climatic conditions, dusty environment, volume of traffic, user characteristics, etc. Therefore, technology available elsewhere may not be suitable for us straight away.

### *2.5.3. Capacity Building*

The pace of urbanisation in the country is very fast and therefore, requirement of building sustainable transport system is also huge which require huge skilled man power to handle such projects. The country is not ready to meet this challenge. The cities really do not have the capabilities to plan and execute such projects. It is therefore, necessary that this gap is bridged and adequate man power is trained.

### *2.5.4. Finances*

The urban transport projects and particularly, metro systems are highly capital intensive. From the point of view of sustainability, environment and climate change, these projects should not be viewed solely on principles of financial viability and, therefore, the Govt. should facilitate and grant necessary tax concessions so that the cost of construction is minimised and the fare structure can be kept as affordableas possible. Similarly, the finances required for the development should also be made available on easy terms.

## 2.6. Urban Infrastructure Issues

The bane of urban traffic in India, is a mix of motorized traffic which moves at higher speed, and, the non-motorized traffic and pedestrians, vying for a place on the already inadequate space on the road. This is so because hardly ever attention is given to clearly demarcate space for the non-motorized traffic. The problem is compounded by inadequate and often chaotic parking and encroachment of footpaths by vendors.

Infrastructure for urban traffic and transportation generally relates to highways, railways, non-motorized systems and pedestrians. This would consist of bridges, viaducts, flyovers, elevated roads, tunnels and underpasses. Invariably, planning of most of these structures in the urban scenario presents a big challenge, because of the constraints from the existing systems, both above ground as well as underground. The latter often presenting the more complex problems. The safety of existing buildings in the vicinity

also has to be addressed, while planning new transportation structures. For the aforesaid reasons often the ideal alignments and choices of the system may not be feasible and, most such projects call for greater engineering skills for successful planning, design and implementation. Furthermore, implanting a large and permanent structure within the existing environs has significant repercussions with often serious detrimental effects on the environment. This aspect though ignored for long has begun to be considered in recent years.

Short length flyovers are very commonly employed to clear existing roads or rail tracks. The ramps for these flyovers however use up precious space at ground level, and often present land acquisition which involve monetary and social costs. Long elevated roads on the other hand are projects of high initial cost, though these are now being increasingly adopted on account of long-term benefits.

The volume of infrastructure required to be added in all big or medium size cities in India, without exception, will be greater than that which exists. The total additional need is thus quite substantial. The inadequacies of city traffic infrastructure are costing the Nation dearly. The need to reduce these and finally overcome them requires speedy action. The challenge therefore is to evolve and develop engineering materials, construction methodologies and practices which would enable the above aim to be met. While R&D related to technological aspect needs continued attention, the volume of Indian infrastructure demands requires to be addressed in relation to resources, constructional materials included. In this respect, due effort is needed to be invested on the utilisation of re-cycled materials.

To handle this large development, the Standards and Guidelines for Highways/ Expressways could have been more imaginatively used for city roads, by modifying present geometrical as well as loading specifications. Apart from that, the addition of the required infrastructure will also entail inputs of a large number of skilled engineering hands at different levels. However, unfortunately, the system of engineering education and training over the last few decades, as well as the professional set up, has done little to ensure that the country can offer the capacity to face up to the challenge. While architects are a class of professionals recognized by an act of Parliament, it is farcical that engineers are not!

## 2.7. Economic Losses

A report on alternative system of urban transport GOI, 1984 recommended that in cities having size of more than 6 million population share of public transport trips is 70%. Another report prepared by MoUD in 1998 on public transport in India brought out that cities having population of more than 5 million plus should have a desirable share of public transport of 80% in a city. This share of public transport revealed in the reports has not been achieved so far due to inadequate mapping of sustainable transport in a city. This has resulted in environmental degradation, loss of time and loss of other monetary benefits. Another report prepared by Delhi Metro Rail Corporation (DMRC 2018) stated that there is a huge cost to the nation in terms of travel time, Vehicle Operating Cost (VOC), fuel cost, road crashes, traffic congestions and environmental degradation. The estimated annual loss, as per this report, if requisite public transport is not provided, is given below:

- For cities having population more than 5 million (8 Cities): ₹ 94,601 crore
- For cities having population in between 2-5 million (12 Cities): ₹ 21,671 crore
- For cities having population in between 1-2 million (33 Cities): ₹ 26,136 crore
- For cities having population more than 1 million (53 Cities): ₹ 142,408 crore

The above data are quite revealing and underline the need of adequate and sustainable public transport system (either rail based or road based or both) in a city. The projected loss in typical cities due to either incomplete or absence of sustainable public transport system are given in Table 2.6 (DMRC Report, 2018).

| Component | Total Annual Loss (₹ in Crore) | | | | | |
|---|---|---|---|---|---|---|
| | Mumbai | Delhi | Kolkata | Chennai | Ahmedabad | Pune |
| Time Cost | 16401 | 5737 | 8873 | 6122 | 2335 | 1242 |
| VOC and Fuel Cost | 12111 | 4012 | 8388 | 4828 | 1906 | 1656 |
| Environment Cost | 1310 | 394 | 945 | 503 | 199 | 205 |
| Other Costs | 1066 | 289 | 671 | 339 | 130 | 133 |

**Table 2.6: Total Annual Loss due to Inadequate Public Transport System**

# IMPROVEMENTS FOR TRAFFIC AND TRANSPORT SYSTEM

**The 3-level grade separator at Ghazipur, NCT Delhi** is located at the critical intersection of NH-24 & Road no.56 in East Delhi. The integration of motorized modes of transportation (cars, buses, trucks, two-wheelers, three-wheelers) as well as cyclists and pedestrians into the scheme was done successfully. The overall landscaping is awe-inspiring with the existing water body forming a very pleasing feature contributing to the acclaimed sustainability of the project.

# 3. IMPROVEMENTS FOR TRAFFIC AND TRANSPORT SYSTEM

## 3.1. Travel Demand Management (TDM)

### *3.1.1. Concept and Need*

TDM is a way of influencing individual travel behaviour and providing expanded options to reduce the actual demand (or number of vehicles) on transportation system of a city. The focus is on managing the demand side of the transportation equation rather than increasing supply by widening or building new roads or expanding the vehicle fleet. As a regional strategy to improve transportation system performance, TDM can reduce highway congestion and traveller delay, improve air quality, and improve access to jobs, schools, and other opportunities using mass transport or integrated multi-modal systems, by using existing infrastructure.

TDM is a system management strategy, which focuses on techniques to provide travel choices for individual travellers. Thus, TDM requires that there be a range of travel choices in public transport and IPT with integration for seamless travel opportunity, which is to be organized by the managing agency. The objective of such TDM strategies is to reduce the demand for private/ single occupancy vehicle trips by diverting trips to transit, walking, and cycling, and therefore, such measures can simultaneously increase throughput of persons along a corridor along with the benefit of reduced energy consumption in passenger-km of travel and consequent reduced pollution.

Providing traveller information and associated support allows travellers to intelligently choose mode, route, destination, and time-of-day for their trips. Information provides travellers a set of real choices for their trips. The merit and attraction of multi-modal traveller information would be the difference in aggregated travel times of such integrated travel mode choices against personalised mode, and the goal is to provide information for people to switch to community trips in public transport vehicles. Providing traveller information can be one of the main ways, and can also be dynamic, providing real-time traffic or transit service information through the use of GPS or other networking devices.

### *3.1.2. Demand Management Techniques*

Travel demand management can be implemented by employers, colleges, and business parks. Employer-based TDM programs are often the most successful ones. New employee orientation is a perfect time to educate employees on the benefits of alternative commuting. Providing information on travel options and helping an employee to establish a routine of using transit, walking or biking can be more effective. Creating a company TDM plan can benefit employees by improving their health, saving them money and freeing up time spent driving. It can also encourage a corporate culture of sustainability and boost employee morale. Implementing a TDM plan can also benefit employers by aiding with employee recruitment and retention. Encouraging and subsidizing the use of transit can allow employees to take back their commute time, arriving to work relaxed and ready to work rather than stressed out from the daily battle with traffic.

Incentives can be used to encourage people to start or continue to seek alternative transportation modes with integrated multi-modal travel

opportunities. One option for employees who participate in a TDM program to get automatic entry to prize draws, where the prizes could be transit passes for those who take the bus, or a gift certificate to a fitness store for those who walk to work. Recognition is also a motivator, and employees can be honoured for their travel choices in various ways including publishing in newsletters. For maximum effectiveness, a TDM plan should have both positive incentives (Pull measures) such as better travel options and negative incentives (Push measures) such as imposition of parking fees and congestion pricing (GIZ, 2009). The different range of TDM options are demonstrated in Figure 3.1.

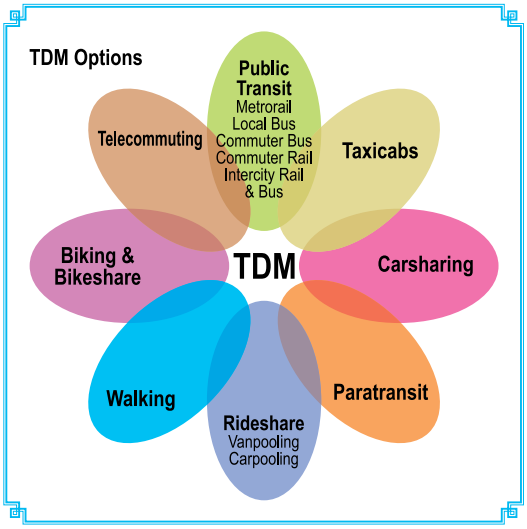



**Figure 3.1: TDM Measures (Source: Mobility Lab)**

### *3.1.3. Shared Mobility*

Shared mobility refers to the shared used of a vehicle, bicycle, or other transportation mode. It is a transportation strategy that allows users to access transportation services on an as-needed basis. Shared mobility is an umbrella term that encompasses a variety of transportation modes including carsharing, bike-sharing, peer-to-peer ridesharing, on-demand ride services, microtransit, and other modes. Each shared mobility service has unique attributes that have a range of impacts on travel behaviour, the environment, and the development of cities and urban areas. Some impacts of shared mobility include enhanced transportation accessibility as well as reduced driving and decreased personal vehicle ownership. Shared mobility programs often yield a variety of environmental, social, and transportation system benefits. These are primarily related to personal vehicle usage and ownership, and vehicle - kilometres - travelled (VKT). Shared mobility networks also retain the potential to expand the reach of public transportation by addressing gaps in existing public transportation systems. They can also provide economic benefits to users in the form of cost savings in some cases (Shaheen, et. al., 2015)[5].

At present, services such as ridesharing, like Shuttle are growing fast and give guarantee of seat and comfort. They are similar to “chartered bus services” along a route with pick-up points, but with much better quality. Car sharing programs also provide individuals the access to a vehicle without the associated ownership, parking, operating, insurance and maintenance costs. Users typically participate in a car share program to supplement the mobility achieved with transit, bicycling, and walking. It is best done by co-workers or those living in the same neighbourhood and travelling to a similar work location. One of the main motivations to carpool is reduced travel expenses. A significant reduction in travel expenses can outweigh the negative impacts to travel time or convenience. One of the keys to a successful carpooling program is providing support for car-poolers through ride

[5]*Shaheen, S., Chan, N., Bansal, A. and Cohen, A. (2015) “Shared Mobility: Definitions, Industry Developments, and Early Understanding.” Transportation Sustainability Research Center, Innovative Mobility Research. July 2015.*

matching programs, preferred parking and other services.

As the private sector innovates and the menu of shared mobility options grows, it is important for the public sector to not only respond with appropriate legislation to protect public safety but also to provide guiding policies to maximize benefits. In addition, transportation planners and operation managers will increasingly need to understand how shared mobility impacts transportation planning and how to maximize the potential to improve system efficiency. The key areas of shared mobility identified by Shaheen, et. al. (2015) are shown in Figure 3.2 which presents current shared mobility models.

### *3.1.4. Organised Intermediate Public Transport (IPT) including NMT*

The absence of organised mass public transport has led to a range of make-shift solutions where a transport service is provided. These may be classified as Intermediate Public Transport (IPT) or para transit and cover the space between private and mass public transport. IPT modes operate mainly in one of two ways. They can be hired by commuters for door-to-door trips or they can operate as informal public transport by carving out fixed routes and fares e.g. share cabs, mini-buses. Cycle rickshaws were amongst the earliest forms of IPT in India. Over time, motorised modes such as taxis, auto rickshaws, battery-operated cycle rickshaws, share taxi-like vehicles or indigenously-made jugaad vehicles, have emerged, which have a longer range. While motorised modes offer higher speeds and carrying capacity, they are also more polluting (IDFC, 2102)[6]. Intermediate public transport (IPT) is extensively used in Indian cities not only in small and medium sized cities but even large cities and play an important role in providing mobility at a low cost to a large section of the society. Some of the major issues and challenges faced by this sector across India are: Inadequate policy/regulatory framework for IPT, no economic stability and social benefits for drivers, Lack

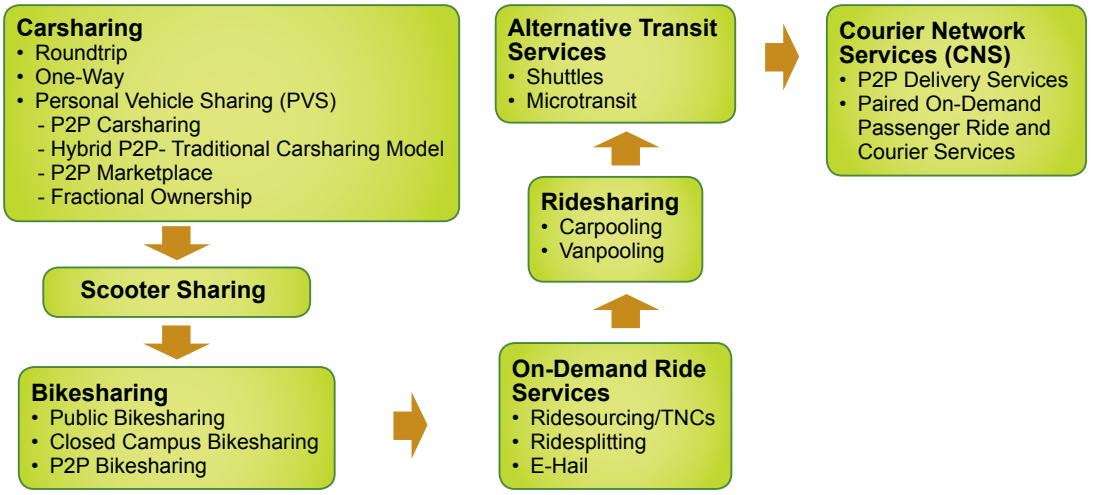



**Figure 3.2: Key Areas of Shared Mobility (Shaheen, et. al., 2015)**

[6]*IDFC (2012) Organizing intermediate public transport for an urbanising India, Quarterly Research Note, No.17, Sep 2012.*

of infrastructure facilities, outdated technology to meet emission standards, lack of usage of modern technology (ITS) for operation control, lack of financial support and lack of institutional ownership of the IPT sector (IUT, 2014)[7].

The taxi space in India is heating up and has been seeing a phenomenal growth in the past 6-7 years. Aggregators, namely, Olacabs, Taxi-for-Sure and Uber have been rapidly growing and expanding their business to promote their service in India. The Indian radio taxi market alone is pegged anywhere between $6-$9 billion dollars by different estimates, and is forecast to grow at 17-20% annually. More importantly, the organised taxi market is still minuscule as compared to rest of the taxi market in India; it constitutes only 4-5% of the market in terms of sheer number of vehicles. The rest is by operators who own fleets of 2-50 cars and typically have a presence in 1 or 2 cities. With this in perspective one can now see why each player is trying to aggressively expand and is raising such humungous funding rounds. The aggregators like Ola, Uber and TFS have just conquered less than 3-4% of the total available market of India so far and have a huge opportunity in front of them. While the aggregator taxi services like Ola and Uber started out many years after the traditional radio taxis like Meru, Mega Cabs, these have already started to eclipse them in terms of city coverage, fleet size, offerings and pricing. Without taking discounts and offers under consideration, the auto is still cheaper than the low-cost alternatives from any of the taxi aggregators. It's still going to take a few more years before taxis will be able to undercut autos (INC42, 2014)[8].

The evolution of the organised taxi sector in India happened in phased manner:

### *Phase 1 – Fully Owned Fleets*

In the initial phase, the market companies owned the complete fleet with the drivers as salaried employees. This was characterized by high capital costs to the company – car loan EMI's, high maintenance costs. While this model facilitated rapid expansion, it also came at a huge cost. Caused high stress levels in drivers and there were driver strikes that affected the service. Bookings were mainly done via telephone calls and cash was the dominant model.

### *Phase 2 – Fleet Aggregation Model*

Companies like Taxi-For-Sure and Ola started this model where small fleet owners or single car owners can put the company brand on the car, and get registered with them. Cars are free to take up non-company rides, but for every company-initiated ride, they pay the company a fixed percentage as commission. This model had low capital expenditure and lower maintenance costs. Booking was done via telephone calls as well as through their websites. While cash was still the dominant payment form, in-cab POS terminal for credit / debit cards started being used as well in this phase.

### *Phase 3 – The Hybrid Model (Current Phase)*

In this model part of the fleet is owned by the company and part of the fleet is from an aggregation model, hence providing the best of both worlds – better control on cab availability and service quality while keeping costs low. Bookings are done via telephone, website as well as mobile apps and the payments via cash, card and wallets.

IPT will continue to play an important role in public transport in Indian cities in the foreseeable future.

[7] *IUT (2014) Improving and Upgrading IPT Vehicles and Services: A Study, Institute of Urban Transport (India), July 2014.*

[8] *INC42 (2014) The Evolution of the Indian Taxi Market - Comparing The Biggies, https://inc42.com/buzz/rajan-anandan-patni-scions-invests-₹-5-cr-aureus-analytics/*

Hence the following issues should be given due attention: Issue of advisories from the MoUD for establishment of the new SPV for IPT (in case not available for city bus services) in cities or functioning of existing SPV (bus services) to integrate services with IPT; participation of stakeholders and experts for their suggestions and feedback; workshops to disseminate the recommendations provided in the report for creating awareness among city officials and general public and Issue of mandate from MoUD for cities to use these recommendations as standard guidelines for IPT vehicles in all cities.

## 3.2. Transport Infrastructure

### *3.2.1. Background*

In the urban environment structures for Traffic and Transportation infrastructure essentially relate to highways, rail-based systems and pedestrians. The projects may take the form of bridges, viaducts, flyovers, elevated roads, tunnels and underpasses. In the planning of most structures in urban environment, physical constraints above and below ground invariably present a big challenge. The geometry, length, width and depth of the structure as well as the location and size of its components need the expertise of experienced hands at the conception stage. The alignment as well as positioning of sub-structure and foundations may not be ideal from the functional or structural point of view as they are often dictated by existing or planned facilities or buildings as shown in Figure 3.3.

**Figure 3.3: Alignment and Pier Locations Dictated by Existing Road**

### *3.2.2. Flyovers and Elevated Structures*

Flyovers are typically of small length often a mere 500m, serving the limiting purpose of spanning across isolated obstacles like roads, rail tracks and streams. Since they require ramps at both ends of the structure to negotiate from ground level to deck level, flyovers result in the occupation of precious space at road level. The acquisition of land to widen the roads is seldom practical in a built environment and can incur huge costs.

Engineers have found an effective solution of increasing the capacity of an existing road by utilising its central verge for locating the supports

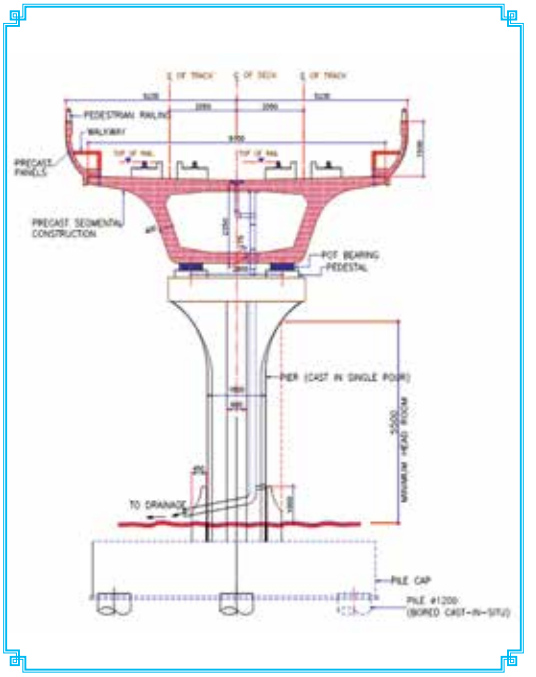



**Figure 3.4:Metro Elevated Viaduct Supported on Piers Located at Central Verge of Road**

and creating an elevated highway or metro rail on the deck above as shown in Figure 3.4. Long cantilevers emanating from narrow piers, are not uncommon for wide decks. This concept needs to be exploited even more frequently so that elevated roads and metros can be constructed without land acquisition or reducing carriageway widths. The advent of the "double-decker" with a two-level structural arrangement, as shown in Figure 3.5, has significantly enhanced the usage of the central verge.

Elevated structures (shown in Figure 3.6) for roads and metros connecting important destinations within the city can be several kilometers long with occasional down ramps and interchanges or metro stations located at selected points to facilitate traffic and transportation needs. While the implementation of flyovers (short length variety) is fairly frequent, it is only occasionally that major cities adopt elevated structures of long length traversing through it as shown in Figure 3.7. The flyover has the limited purpose of getting the traffic across an existing obstacle such as roads and rail tracks. Experience has shown that there is invariably a bottleneck at the end of the flyover due to the confluence of traffic coming from the ground level road and that descending from the flyover. The succession of flyovers on Ring Road in Delhi is an example of such planning. It is recommended that long elevated

**Figure 3.6: Sharply Curved Flyover Under Construction**

**Figure 3.5: Double-decker" or Two-level Structural Arrangement supported on the Central Verge Caters to Metro Lines at the Top and 6-lane Highway at the Lower Level**

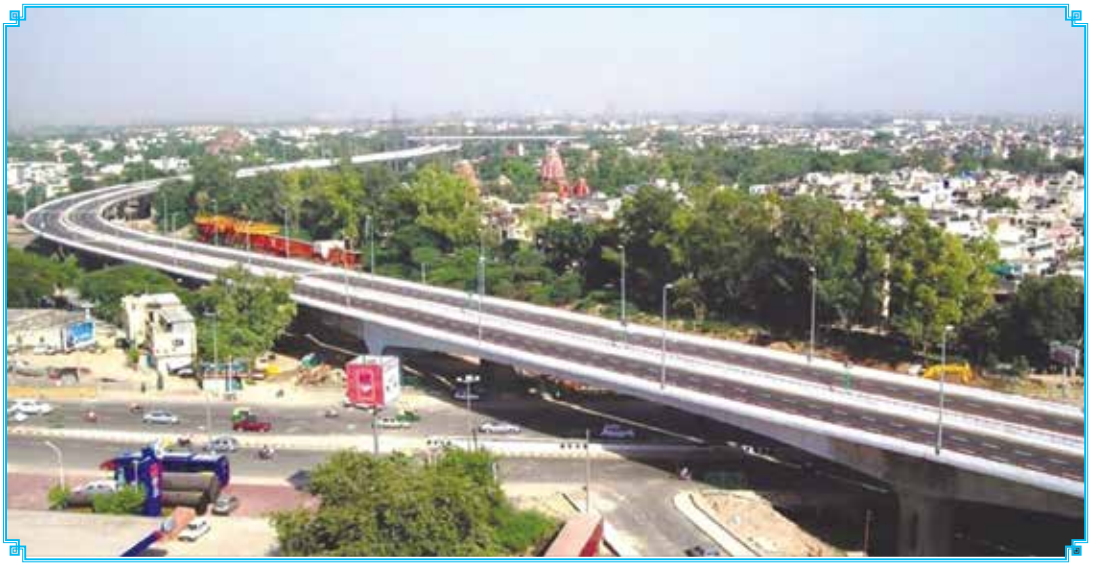


**Figure 3.7: Long Elevated Corridor: Barapulla Elevated Road, New Delhi**

corridors be implemented such as the Barapullah Elevated Road in the same city which is expected to be completed in the year 2020.

The reason for infrequent adoption of long length elevated structures relates to higher initial cost and the ignorance of environmental impact of such a structure.

### *3.2.3. Pedestrians and Non-Motorized Vehicles Infrastructure*

Pedestrians, cyclists and non-motorized vehicles require distinct considerations and must form an integral part of the Traffic and Transportation infrastructure planned for the urban environment. Catering to specially-abled persons should be one of the aims of the planning. Segregating this traffic from motorized vehicles requires particular attention. The Mukerba Chowk Interchange, shown in Figure 3.8, which is located on the outskirts of Delhi on NH-1 has been planned such that there is signal-free movement as well as segregation of cars and buses from pedestrians and cyclists.

The location and design of over-bridges and underpasses for facilitating movements of pedestrians, cyclists and non-motorized vehicles must be coordinated with the ground level situation. The entry/exit points and incorporation of staircases, lifts and escalators must be judiciously positioned so at to ensure that there is maximum utilization of these facilities. The safety of the supporting structure of the bridge should also be ensured. Figure 3.9 and 3.10 show the good and

**Figure 3.8: An Aerial Photograph of an Elevated Road & Interchange in a Densely Built Environment**

**Figure 3.9: Arch Bridge is Good Option for Foot Over Bridge**

**Figure 3.11:Underpass in Urban Environment**
*Note: Segregation and Reduced Vertical Clearance provided for Non-Motorised Traffic*

the bad practice respectively in this regard. The vertical clearances required for such traffic are much smaller than those required for motorized vehicles. Figure 3.11 shows the example of an underpass which caters to motorized traffic as well as cyclists and pedestrians.

### *3.2.4. Underpasses, Tunnels, Underground Metro Stations*

While above ground physical constraints can be visualized in advance and hence taken into account in the planning stages, the location and identification of underground utilities crisscrossing below ground shown in Figure 3.12 and 3.13 and the effect on existing buildings in the vicinity shown in Figure 3.14, can pose serious problems. A plethora of agencies are involved in the establishment and running of underground utilities and the records, if available, are woefully incomplete. Also, information regarding condition and status of existing buildings including their foundations are always difficult to come by. It is not unusual that the alignment of the metro tunnel (shown in Figure 3.15) goes below existing buildings. Complete digitisation of the records of utilities and structures within the city limits should be carried out by the Municipal authorities and should be freely available to agencies involved in any construction project in the concerned

**Figure 3.10: Foot Over Bridge With Supports at Median Verge are Hazardous**

**Figure 3.12: Underground Utilities Hinder Foundation Construction**

**Figure 3.13: Obstructing Pipeline Temporarily Supported**

**Figure 3.15: Underground Metro Tunnel Using Precast Segments**

**Figure 3.14: Metro Construction in Close Vicinity to Existing Building**

**Figure 3.16: Three Level Interchange Involving Subway Structure**

area. The utilities which are openly visible can be surveyed by direct measurements to the object. It is the buried utilities which are of great concern.

Special electromagnetic and geophysical scanning techniques including high frequency GPR (Ground Penetrating Radar) based on sophisticated instrumentations are now available for the rapid and non-invasive detection of underground utilities such as sewers, drains, water lines, power cables, fiber optic cables, telephone lines or metallic as well as non-conductive pipe and ducts. These are already being used in many countries including India. Underpasses by themselves or in combination with more than two levels of traffic integration facilitation at interchanges often require intense engineering inputs shown in Figure 3.16 and 3.17.

Underground Metro structures require enormous contiguous areas to be dug deep below the ground level. As shown in Figure 3.18 to 3.20 these can be often very close to existing structures whose safety needs to be ensured. The alignment of the Metro tunnels connecting the underground stations may often have to traverse below existing buildings. Special expertise of Structural and Geotechnical Engineering requires to be mobilized to ensure safety of public and workmen in such situations.

**Figure 3.17: Level Traffic Interchange Integrating Road and Metro**

**Figure 3.19: Metro Underground Construction Challenges: Buildings in Vicinity**

### *3.2.5. Special Safety Considerations*

A special requirement for structures in urban environment relates to safety not only during service but also during construction. Some instances where serious concerns of safety have emerged during service phases of urban infrastructure are shown in Figure 3.21 and 3.22. Many of the accidents and collapses in structures happen during the construction phase. See for example Figure 3.23. Safety during construction has to be ensured not only for workers but also for road users.

There have been many instances of major damage to bridge piers arising out of vehicle collision in urban structures and other viaducts. While safety barriers in front of bridge piers give some measure of protection, the sub-structure should be designed specifically for vehicle collision loads. Vehicle collision on parapets induces forces on parapets, superstructures as well as piers/ structures supported at ground level including median verge. Recent IRC codes incorporate the loading criteria for vehicle collisions. A pedestrian bridge with no supports at median verge is shown in Figure 3.9.

Finally, separate facilities and the segregation of pedestrian and non-motorized traffic from vehicular traffic should be ensured. A vehicular barrier is required at the edge of the carriageway

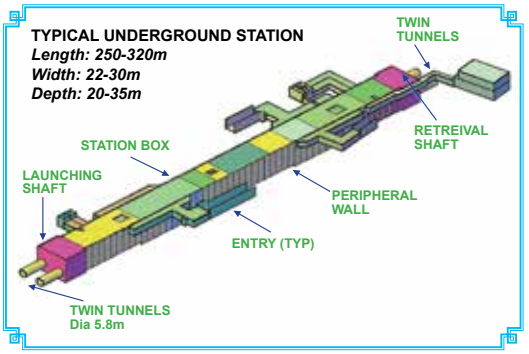



**Figure 3.18:Typical Underground Station for Metro**

**Figure 3.20: Metro Construction in Close Vicinity to Existing Building**

**Figure 3.21: Truck Crashes Against Flimsy Parapet**

**Figure 3.23: A Mishap During the Construction of a Bridge**

**Figure 3.22: Median Supports are Not Safe**

width, while a light pedestrian railing may be provided at the edge of the structure.

### *3.2.6. Aesthetics and Environment Concerns*

The importance of aesthetics in relation to urban infrastructure has been increasingly realized over the last few decades, because the implication of implanting a large and permanent structure within the existing environs has significant repercussions with often serious detrimental effects on the environment.

Due to its sheer size and importance in sociological terms, an infrastructure project has a high impact on the urban environment. It has been found that the most important decisions relating to aesthetics are taken during the "evolution" or "formative" stages of design work. Later, the corrections from aesthetic considerations of badly conceived solutions can only result in marginal improvements unless the whole concept undergoes major modifications.

An urban structure must necessarily perform two functions: a utilitarian one facilitating traffic and, an aesthetic one which enhances the quality of the environment.

### *3.2.7. Construction Techniques*

A number of construction technologies have been developed in recent times, which are specifically suited to infrastructure projects in the urban environment.

The main objectives of such technologies are:

- Use of concept of accelerated bridge construction.
- Economical and efficient structures to keep the costs under control.
- Elimination of those construction activities at site which can very well be done in an offsite facility.
- Use of prefab construction as much as possible for improved quality and finish.

- High priority to aesthetic appeal
  - Durability (Design life is 100-120 years for bridges, underground structure etc.)
  - Concerns of sustainability and “green” project delivery including landscaping, LED lighting etc.
  - Minimum disturbance to traffic during construction
  - Minimum re-location of underground services
  - In-service maintenance without excessive difficulties
  - Protection from damage and accidents during construction and in service
  - The overwhelming need is to use prefabrication techniques and to reduce casting-in-situ to an absolute minimum.

### 3.2.8. Geometric and Loading Standards

The current Indian Roads Congress provisions, and, a few other norms for Indian cities or abroad given below, describe the scenario relevant to this section.

#### Geometrics

The IRC code on General Features of Design, IRC-5-2015, stipulates the road width should be calculated on the following basis:

- The width of carriageway shall not be less than 4.25 m for a single lane bridge, 7.5 m for a two-lane bridge and shall be increased by 3.5 m for every additional lane of traffic for a multiple lane bridge. If a median/central verge is constructed in a wide bridge thus providing two separate carriageways, the carriageway on each side of the median shall provide for at least two lanes of traffic and width thereof shall individually comply with the minimum requirements stipulated above.
- The median shall be a minimum of 1.2 m wide, in which case crash barriers shall be provided in the median.
- IRC-5-2015 also indicates that the minimum vertical clearance provided over roads should be 5.0 m for non-urban areas and 5.5 m for urban areas. In case of structures over local or collector streets, where only light commercial vehicles are plying and where alternative routes for heavy commercial vehicles and fire tenders are available within a short distance, the authorities may relax the clearance requirements stated above.
- At locations where over-dimensioned vehicles are frequently plying, the authorities may consider providing increased vertical clearance. For footways and cycle tracks, a minimum vertical clearance of 2.25 m shall be followed.

#### Loading Standards

The IRC code on Loads and Load Combinations, IRC-6-2017, indicates that the design should cater to one or more of the specified hypothetical vehicles or trains (of the military type), viz. Class 70R (wheeled and Tracked), Class A & Class B.

In addition, IRC-6-2017 also stipulates two additional loading conditions. The first is the Congestion factor (values varying from 1.15 to 1.7 for spans ranging from 10.0 m to 70 m and above) for bridges and flyovers/ grade separators and is applicable on the effects of the specified hypothetical vehicles. This Factor becomes operative for structures close to areas such as ports, heavy industries and mines and any other areas where frequent congestion of heavy vehicles may occur. The second is the IRC Class SV vehicle loading applicable for Special Multi-Axle Hydraulic Trailer vehicle (20-axle 385 t GVW with a 20 t prime mover) plying on the structure by itself.IRC 5 mentions that the loads, special local conditions and traffic intensity for which a bridge is to be designed, shall be prescribed by the authorities as per relevant clauses of IRC 6.

### *Norms for PWD Delhi Flyovers*

The norms of PWD Delhi have taken a pragmatic view in the past for road widths for 2x3 lane flyovers in the city which has been the frequently used configuration. The total width for each carriageway has been fixed at 3.0 X 3.0 m = 9.0 m. One such project is the Barapulla Elevated Road, Fig. 3.7, constructed in New Delhi for the 2010 Commonwealth Games.

### *Norms for Mumbai Flyovers*

In the 90s a few flyovers were built by BMRDA (now called MMRDA) where the criteria were modified so as to exclude the 70 R loading completely. They took the pragmatic view that such heavy loads can pass on the at-grade roads and the flyover structure need not be burdened with the same.

### *Norms in Other Countries*

In Singapore the existing lane widths lie generally between 3.0 and 3.3 m. In a recent move by the Land Transport Authority (LTA), it is proposed that all roads should have a lane width of not more than 2.9 m, leaving greater width for catering to the cycle lane adjacent to the kerb.

In Europe, road width varies in different countries the minimum width of lanes is generally between 2.5 to 3.25 m. In Holland most streets with many shops are pedestrianized. Wherever this is not done or not possible to do, the speed of vehicles is limited to 30 km/h.

## *3.2.9. Summary*

The provisions in the present IRC Codes are flexible to the extent that specific projects can formulate some deviations for geometric and loading standards. More options can be included in the IRC codes and the concerned authorities encouraged to exercise them in consultation with traffic experts.

From the point of view of safety of public, the facilitation of public transport as well as, pedestrians and non-motorized vehicles is important. The speed of motorized vehicles in heavily populated area should be restricted to about 30 km/h. The unhindered access of heavy vehicles other than those meant for public transport should be prohibited in the city, as is the case in most advanced countries. An excellent example has been set by the recently inaugurated 135 km long ₹ 11,000 crore Eastern Peripheral Expressway for Delhi (shown in Figure 3.24), by which the vehicles passing through Delhi would be drastically reduced. Finally, innovative planning is required so that cars and buses are segregated from other road users, especially pedestrians and cyclists.

Each urban infrastructure project is unique with its own set of local conditions and constraints. However, the accent on public transport, pedestrians and non-motorized vehicles are the keys to sustainability of such projects.

The important elements of planning structures for traffic and transportation in the urban environment revolve around rapid constructions


**Figure 3.24: Delhi's Eastern Peripheral Expressway and Western Peripheral Expressway**

and reducing site activities to the minimum during implementation stages. It must be possible to build without shutting or slowing down anything. To achieve this not only requires technology but also a sensitive, creative and imaginative approach so that the present and future generations feel proud of the acquisition of an infrastructure project, that is implanted in their midst.

Finally, we must have competent professionals involved in all key decisions so that the shape and form of the facility can reach the levels of safety, security and sustainability that is concomitant with the attention, effort and expenditure on such projects.

## 3.3. Multi-Modal Transport and Reduction of Private Vehicles

### *3.3.1. Background*

Freedom for movement is an eternal need the techno-social-economic revolution is driving transport demand in an unprecedented way (like in lightning speed), where distance is no longer considered to be a deterrent. It is understood that in future, the demand for travel will rise faster than population or average income or even the rate of GDP growth, just because of the pressure of urbanisation. The primary requirement will be for the personal mobility, which is rising in many countries at more than 1.5 times the GDP growth. Further, the cultures and technologies have already converged in case of personal mobility and transport demand, especially in urban areas. So far, an indiscriminate policy of grade-separations, widening of roads, more signalisation, etc. (favouring primarily personalised modes only) in cities have led to a “Black Hole Theory of Transport Development”. Fragmented systems of overlapping networks of public, private and para-transit modes exist without any complementarity along with aggravated situation of missing NMT and pedestrian infrastructure. In future, the transport will be demanded as equitable, seamless, safe, autonomous, zero-pollution, faster and productive.

In India, the total urban population living in cities and towns in any particular class has increased consistently largely due to the rapid pace of urbanisation noticed in last two decades. The census 2011 data reveals that approximately 377 million people live in 7935 urban centers[9] of India. In India, the total urban population living in cities and towns in any particular class has increased consistently largely due to the rapid pace of urbanisation noticed in last two decades. In 2011, there were three cities with more than 10 million and 53 cities with more than 1 million population (IIHS, 2012). As depicted in Figure 3.25, a total of 13% of the country’s population lived in cities with more than 1 million population, while about 19% lived in the remaining urban centers. Among smaller cities, there were a total of 7,882 urban centers with population ranging from 50,000 to 1 million, which are generally found to be heavily dependent on IPT and informal transport. Urban transport is an important parameter of the economic efficiency of a city and the relevant infrastructure is instrumental for healthy growth. Urban transport is an important parameter of the economic efficiency of a city and the relevant infrastructure is instrumental for healthy growth.

Urban population in India has grown from 27% in 2001 to 31% in 2011; and Indian economy has also shifted from agriculture based economy in 1950s to an economy dominated today by service sector. Cities contributed 54% of service sector component of National GDP in 2011 and its contribution is expected to grow in coming decades. Further, MGI report on urban India projected that cities will contribute 75% of the National GDP by 2030. Urban transport demand can be met by various modes of transport, which

[9] *population greater than 5,000 is classified as an Urban Center*

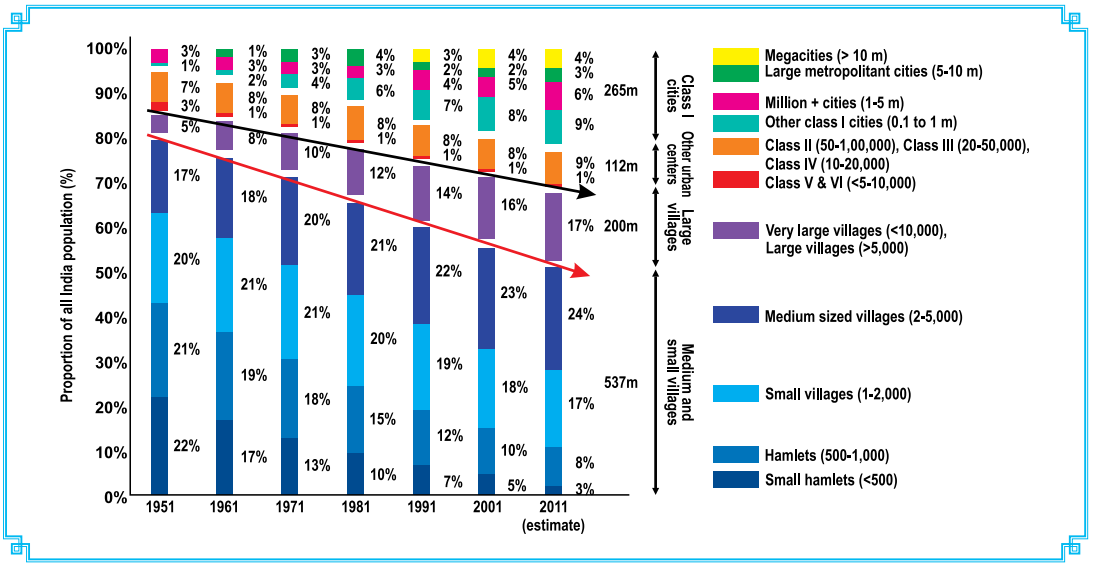



**Figure 3.25: Distribution of India's Population by Settlement Size**
*(Source: Urban India 2011: Evidence, Indian Institute of Human Settlements, January 2012)*

differ from one another in technical performance and economic advantages, as well as in terms of their usefulness in serving the demand.

The 9th Five year Plan (1997-2002) recognized that heavy investment was required to develop rail based public transport system in cities and National Urban Transport Fund was created. Government of India funded ₹ 56,182 crore to develop Metro Rail system in 10 cities, which is 25% of the total project costs. BRT systems were introduced in 10 cities in India viz, Delhi, Ahmedabad, Pune, Surat, Jaipur, Indore, Bhopal, Visakhapatnam, Vijayawada and Rajkot with a total approved cost of ₹ 4,532.39 crore (Tiwari,et. al., 2010), where 50% of the cost was funded by central government through JNNURM program. Supply side policies for development of Trunk-route public transport system were reflected in the earlier 11th and 12th Five year plan of the erstwhile Planning Commission, and Three Year Action Plan of NITI Aayog. However, full potential of public transport system are not achieved in cities as the first and last mile connectivity in terms of access and egress trips through other modes are not planned and implemented along with the public mass transit system itself.

As India aspires to become a major economy[10] with very large urban agglomerations, the need to rapidly modernize and integrate its public transport is imperative. However, several challenges would need to be addressed in this endeavour. It is estimated that in India approximately 88 million trips (70 million by buses, approximately 18 million by railways and 0.23 million by air) are made on public transport on a daily basis which translates to 6-9% of total trips being catered to by public transport as against 30-35% in most countries across the world. Clearly there is a need to provide more public transport in India as it has numerous benefits.

[10] *Gross National income per capita ranging between USD 1006-3955*

India's public transport needs to grow rapidly as the country urbanises at a fast pace. As per Census 2011 (the population of India is 1.21 billion), India is about 31% urbanised and cities contributed almost 66% to the Gross Domestic Product (GDP) of the Country. It is expected that by 2030, 40% of population will live in cities and also contribute to 75% of the GDP. Practically, the cities are becoming the engines of economic growth. The Ministry of Housing and Urban Affairs estimates that ₹ 39,20,000 crore (USD 600 billion) needs to be invested during the period 2011-31 out of which 44% is to be allocated to urban roads and 11.50% to mass transit systems.

The lack of integrated approach in planning urban transport systems in absence of an umbrella authority, has led to the development of transport systems, which has manifested in a skewed distribution of demand with serious bottlenecks in efficiency of urban transport infrastructure. At the extreme, often it is found that deficient policy has encouraged development of one mode at the cost of another. The development of transport systems in a multi-modal environment can achieve seamless service provision to the customers at all times. However, such systems can be developed by serious and deliberate integration at planning, operations and business management stages. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, are the 17 Sustainable Development Goals (SDGs), which call for urgent action by all countries - developed and developing - in a global partnership. As mentioned in the list of goals, the Sustainable cities and communities and Climate change are to be focussed in the long term transportation plans.

### *Increase in Personal Vehicles*

Even though personal automobile transport is expensive, it also is often the fastest mode of travel and the most comfortable. However, commuters often need to rely on alternative modes for several reasons:

- Many people cannot drive due to a variety of reasons including economic, capacity and health constraints;
- People prefer using alternative modes, like walking and cycling which are more enjoyable and provide exercise (VTPI, 2017)

Urbanisation and motorisation are inevitable in view of fast growth of purchasing power of the new generation in a stable economy. However, urban transport need not be biased to serve, promote or facilitate only private modes of travel. The indiscriminate provision of flyovers, widening of road for motorised modes depriving appropriate rights of way to other modes, more signalisation, etc. and all such policies adopted in every city of the country are the glaring examples of undesirable transport development. Private car ownership and registered vehicles in million plus cities in India increased from 15.9 million vehicles in 2001 to 53.4 million vehicles in 2012 with an annual average growth rate of 11.6%. The users of personalised vehicles create congestion and parking problems. As per recent data (ET, 2018), average distances travelled per car trip in Indian cities are shown in Table 3.1.

All of the above issues indicate an existing latent demand of commuters in Indian (and worldwide) cities for alternative modes, but there are limitations like poor walking and cycling infrastructure and inadequate public transit services (VTPI, 2017). Historically, the public transport systems were plagued with inefficiency, lack of productivity, overstaffing, high operating costs, and huge subsidy requirements. Required high-capacity systems were not developed/ implemented till the problems had gone out of hand and consequent negative social impact was the shift from public transport to private modes, especially with an unreasonable growth in 2-wheeler population.

| City | Average distanceper car trip (km) |
|---|---|
| Chennai | 15.52 |
| Mumbai | 13.95 |
| Bengaluru | 13.71 |
| Hyderabad | 13.05 |
| Delhi | 12.74 |
| Ahmedabad | 10.07 |
| Pune | 9.05 |
| Kolkata | 4.82 |

**Table 3.1: Car Dependency in Indian Cities**

There are two important issues to be addressed to salvage the situation. First, mass transit requirement of the metro-cities and other large cities need to be addressed on a priority basis. Secondly, there is need for strategic land use development policy in all large cities with an aim to integrate land use with mass transit planning models to guide future growth process of cities making it compatible to the transport infrastructure developments.

Taking into account the growing urbanisation and its impact on intra-urban and sub-urban rail transport, MRTS and sub-urban rail systems are required to be integrated. In a multi-modal transport system, the urban transit systems (track-based systems and the buses) should complement and not compete with each other in the system. However, the solutions are expensive and require massive mobilisation of resources for investments that have long gestation periods Table 3.2 presents the percentage share of buses and cars in major cities in India.

| Metropolitan Cities | % Cars | % Bus |
|---|---|---|
| Ahmedabad | 12.84 | 1.65 |
| Bengaluru | 13.97 | 0.67 |
| Bhopal | 6.93 | 0.78 |
| Chennai | 17.29 | 0.43 |
| Delhi | 27.77 | 1.31 |
| Lucknow | 12.78 | 0.62 |
| Mumbai | 30.56 | 1.19 |
| Patna | 11.55 | 1.02 |

**Table 3.2: Percentage Share of Buses and Cars to Total Motor Vehicles**

In an optimal transport system also people would not forego driving altogether. However, multi-modal and integrated system would provide better and efficient transport options with incentives, where people can rationally choose to drive less, and rely more on alternative modes (VTPI, 2017).

### *Inadequate Public Transport Supply in India*

Public transport provides satisfaction to collective well being rather than individual desires/needs. Though the choice between public transport and private transport is an individual decision, it is also influenced by government policies and Urban Local Body's (ULB) decisions such as parking fees, vehicle tax, etc. As shown in Table 3.3 city-wise vehicle registration data when compared to the fleet strength of the formal public transport reveal interesting insights on the important role of contract buses and para-transit vehicles.

A general decline in public transport trips is noticeable in cities of all sizes when the RITES study (1994) is compared to the Wilbur Smith Associates report (2007) as shown in Table 3.4. The average trip length (ATL) in the cities of various sizes was also studied by WSA in 2007, and its values are given in Table 3.5. In general the study found that larger cities had higher percentage of trips served by public transport, and rapid growth of the large cities suggested a further rise in public transport demand with longer ATLs.

For most cities, bus is the predominant mode of public transport both in intercity as well as intra-city travel. India is 31% urbanised (2011 census) currently and this is expected to increase to 40% by the year 2031. Currently, about 70 million trips per day are being catered to by 140,000

| City | Mumbai | Delhi | Chennai | Bengaluru | Kolkata | Pune |
|---|---|---|---|---|---|---|
| | BEST | DTC | MTC | BMTC | Calcutta STC | Pune MPML |
| Public Transport Buses operated by State Road Transport Undertaking (SRTU) | 4,652 | 5,771 | 3,414 | 6,111 | 956 | 1,549 |
| Other Buses (Registered buses excluding SRTU buses) | 8,189 | 39,986 | 33,791 | 22,150 | 3,293 | 13,459 |
| Para transit registered commercial transport vehicles including taxis and 3 to 6 seater passenger vehicles | 1,59,629 | 2,53,532 | 1,74,314 | 1,62,431 | 49,648 | 78,778 |

*(Source: Press Information Bureau. http://pibmumbai.gov.in/scripts/detail.asp?releaseId=E2012FR48)*

**Table 3.3: Patterns of Public Transport in Selected Indian Cities**

| City Category | City Population (Range in Millions) | RITES, 1994 | WSA, 2007 |
|---|---|---|---|
| 1 | < 0.5 | 14.9 - 22.7% | 0–15.6% |
| 2 | 0.5-1 | 22.7–29.1% | 0–22.5% |
| 3 | 1.0–2 | 28.1–35.6% | 0- 50.8% |
| 4 | 2–4 | 35.6–45.8% | 0.2 - 22.2% |
| 5 | 4–8 | 45.8–59.7% | 11.2-32.1% |
| 6 | Above 8 | 59.7–78.7% | 35.2–54.0% |

*Source: National Transport Development Policy Committee (NTDPC) Report-Vol.03_Part 2Ch 05.indd Pg. 390, Mar 2014.*

**Table 3.4: Public Transport Share Comparison, 1994 and 2007**

government run buses in the country. With a vision to cater to 50% of the urban transport trips using public transport (assuming public transport shall be provided by buses primarily), and based on present passenger ridership per bus, it is estimated that an additional 460,000 buses shall be required to cater to the urban public transport demand in the year 2031 in addition to various other modes of public transport.

Table 3.6 shows the current estimated percentage share of public transport among motorised trips in the five largest Indian cities. Pune has the lowest share of public transport in the motorised trips at around 17%.

| Category | City Size (Population), Range in Millions | Average Trip Length (ATL) |
|---|---|---|
| 1 | < 0.5 | 2.4 |
| 2 | 0.5-1 | 2.5 |
| 3 | 1.00–2 | 4.7 |
| 4 | 2–4 | 5.7 |
| 5 | 4–8 | 7.2 |
| 6 | Above 8 | 10.4 |
| | National Average | 7.7 |

*Source: Wilbur Smith Associates Study report (2007)*

**Table 3.5: Average Trip Length (ATL) in Cities of Different Sizes**

| City | Public Transport Share (%) |
|---|---|
| Mumbai | 78 |
| Kolkata | 77 |
| Delhi | 54 |
| Chennai | 47 |
| Bengaluru | 42 |
| Hyderabad | 40 |
| Ahmedabad | 33 |
| Pune | 17 |

*(Source: The Economic Times, October 2018)*

**Table 3.6: Share of Public Transport Trips in Indian Cities in 2017**

Very few Indian cities currently have organized, registered and regulated public transport systems. Organized city bus services operate now in about 65 cities, an increase from only 20 cities in 2006. The RITES Study of 1994 established the potential combined share of public transport modes in various city sizes as shown in the Figure 3.26. See also the Appendix in this context.

It is evident from Table 3.7 that Indian cities appear to lag behind in the physical coverage of public transport network compared to most cities across the globe.

### *Urban Transport Modal Share across Indian Cities*

Public transport starts with a disadvantage compared to the door-to-door flexibility of private transport. Thus, there have to be good reasons to set about creating a multi-modal system. Further, at present there is inadequate understanding of, and inconclusive data on, the modal share of public transport and distribution between these various transport modes, across city types and sizes in India. The variations in reported modal share from a few studies are reflected in Table 3.8. It is clear that there is no consensus among transport planners about the true modal split of trips in any city. Particularly lacking is the information on urban freight movement, which is commonly believed to be up to 15% of the traffic.

Wilbur Smith Associates (WSA) study report

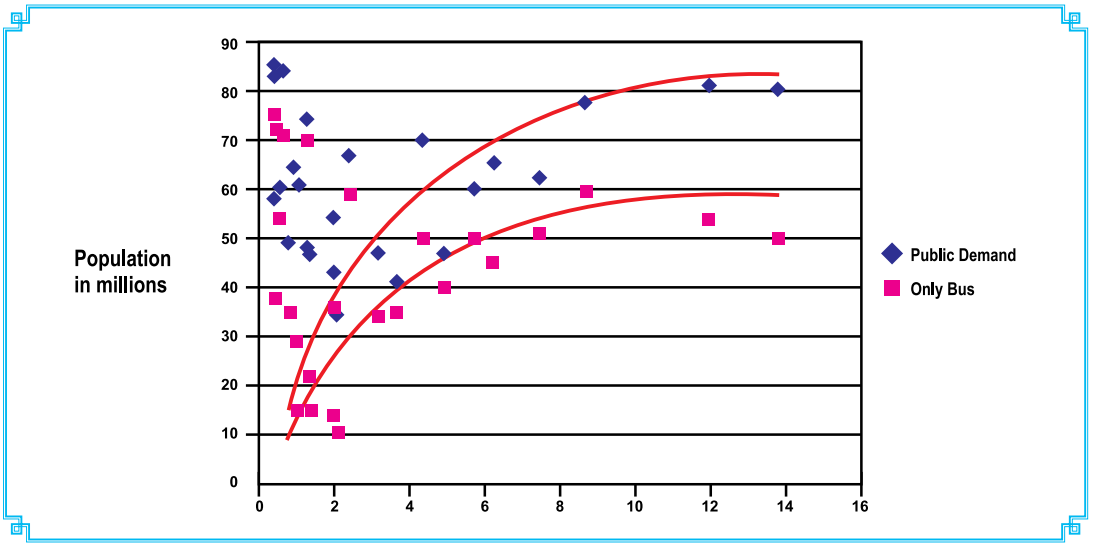



**Figure 3.26: Potential Share of Public Transport vs City Sizes**

| City | Metropolitan Area | | Bus | | MRT | | Bus Fleet/ 1000 Persons | MRT Km/ 1000 Persons |
|---|---|---|---|---|---|---|---|---|
| | Population Persons ('000) | Area (Km²) | Fleet Size | Daily Ridership (Million) | Km | Daily Ridership (Million) | | |
| Beijing | 20186 | 16411 | 21628 | 13.8 | 554 | 6.7 | 1.07 | 0.03 |
| Hong Kong | 7184 | 1104 | 5743 | 3.8 | 178 | 4 | 0.8 | 0.02 |
| Shanghai | 23475 | 6341 | 16235 | 7.6 | 588 | 6.2 | 0.69 | 0.03 |
| Singapore | 5312 | 716 | 4212 | 3.5 | 167 | 2.2 | 0.79 | 0.03 |
| London | 8302 | 1572 | 7500 | 6.4 | 402 | 3.2 | 0.9 | 0.05 |
| New York | 8337 | 790 | 4344 | 1.8 | 370 | 4.5 | 0.52 | 0.04 |
| Seoul | 10442 | 605 | 7512 | 4.6 | 327 | 6.9 | 0.72 | 0.03 |
| Tokyo | 13277 | 2189 | 1462 | 0.6 | 305 | 2.2 | 0.11 | 0.02 |
| Delhi | 16788 | 1483 | 5942 | 4.8 | 215* | 2.7 | 0.35 | 0.01 |

*Source: Key transport statistics in world cities, Pan Di, September 2013*
** Note: The MRT network in Delhi as on November 2018 is 314 km*

**Table 3.7: Public Transport Systems across the Globe**

| City Size Category (Million Population) | Walk | Non-Motorised Transport | | Intermediate Public Transport | | Public Transport | Motorised Personal Transport | |
|---|---|---|---|---|---|---|---|---|
| | | Cycle | Rickshaw | Auto Rickshaw | Others | | Cars | Two Wheelers |
| >8.0* | 22 | 8 | | 7 | | 44 | 10 | 9 |
| >5.0* | 29 | 8 | 1 | 1 | | 47 | 4 | 10 |
| 4-8**** | 25 | 11 | 7 | 7 | | 21 | 10 | 26 |
| 2-5* | 29 | 13 | 2 | 7 | | 33 | | 24 |
| 2-4**** | 25 | 18 | | 6 | | 10 | 12 | 29 |
| 1-2* | 30 | 8 | 5 | 2 | | 24 | 1 | 30 |
| 1-2**** | 24 | 19 | | 8 | | 13 | 1 | 24 |
| 0.5-1* | 32 | 10 | 9 | 3 | | 21 | 2 | 23 |
| 0.5-1**** | 32 | 20 | | 3 | | 9 | 12 | 24 |
| <0.5 (category 1a)**** | 34 | 3 | | 5 | | 5 | 27 | 26 |
| <0.5 (category1b for hilly towns)**** | 57 | 1 | | 0 | | 8 | 28 | 6 |
| 0.1-0.5* | 38 | 15 | 12 | 3 | | 13 | 1 | 18 |
| 0.5-0.1* | 38 | 17 | 13 | 4 | | 11 | 1 | 16 |

*Source: *Tiwari (2011); **Pendakur 2002 and World Bank 2002; ***Data from various City Development Plans available at http://www.jnnurm.nic.in/ (accessed on 20 January 2014); ****Wilbur Smith Associates, GOI (2007).*
*Note: Figures are in % except where mentioned otherwise*

**Table 3.8: Consolidated Figures from Various Reports on Modal Split in Indian Cities (in %)**

published in 2007 has a very wide range of data from different sources. This report clearly states that Kolkata had the highest share of public transport of 54% followed by Kochi at 51% and so on as enlisted in Table 3.9.

The transport modes used and the modal mix depend on the population, form and size, availability and quality of road infrastructure and the existing trip lengths of a city. The objective should be to restore balance in the use of road space for walk and non-motorised transport and promotion for the use of public transport discouraging the use of private motorised vehicles.

Table 3.10 shows desirable modal shares for different city sizes based on trip length distributions in Indian cities. Priority in planning for various modes should be favouring more affordable and efficient ones (in terms of space, energy and other costs) as given below in order of priority:

- Walk and bicycle
- Public transport including Para-transit
- Personal vehicle transport

Looking at it in another way, Table 3.11 gives a desirable structure of integrated transport modes (vehicular modes) in the cities of different sizes.

A recent study by Arthur D'Little (2018) ranked cities using a global urban mobility index based on a series of measures including maturity,

| S. No. | City | Walk | Cycle | Two Wheelers | Public Transport | Car | IPT | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Delhi | 21% | 12% | 5% | 43% | 14% | 6% | 100% |
| 2 | Mumbai | 27% | 6% | 7% | 45% | 8% | 7% | 100% |
| 3 | Kolkata | 19% | 11% | 4% | 54% | 8% | 4% | 100% |
| 4 | Chennai | 22% | 9% | 20% | 31% | 10% | 8% | 100% |
| 5 | Bengaluru | 26% | 7% | 17% | 35% | 8% | 7% | 100% |
| 6 | Hyderabad | 22% | 9% | 19% | 35% | 9% | 7% | 100% |
| 7 | Kochi | 16% | 5% | 14% | 51% | 9% | 6% | 100% |

*Source: Wilbur Smith Associates Report , Government of India, 2007*

**Table 3.9: Share of Public Transport and Other Modes in Selected Metropolitan Cities in India in 2007**

| City Size in Millions | 0.05-01 | 0.1-0.5 | 0.5-1 | 1-2 | 2-5 | >5 |
|---|---|---|---|---|---|---|
| Walk | 30 | 30 | 30 | 30 | 25 | 25 |
| Cycle | 25 | 20 | 15 | 12 | 10 | 10 |
| Rickshaw | 12 | 10 | 8 | 6 | 1 | 1 |
| Auto Rickshaw | 8 | 3 | 5 | 3 | 3 | 1 |
| PT | 12 | 15 | 15 | 20 | 33 | 38 |
| Cars | 1 | 1 | 2 | 4 | 8 | 10 |
| MTW | 12 | 21 | 25 | 25 | 20 | 15 |

*Note: MTW: Motorised two-wheeler; PT: Public transit;*
*Source: National Transport Development Policy Committee (NTDPC) Report-Vol.03_Part 2Ch 05.indd Pg.414, Mar 2014*

**Table 3.10: Desirable Modal Shares for Different Indian City Sizes**

| City Size (Population in Million) | Integrated Transport Systems | | | | | | |
|---|---|---|---|---|---|---|---|
| | Mass Rapid Transit | Suburban/ Comm. Rail | Bus Transit | Bus | Private Modes | IPT | NMT |
| 0.005 to 0.01 | × | × | × | × | ✓ | ✓ | ✓ |
| 0.01 to 0.05 | × | × | × | ✓ | ✓ | ✓ | ✓ |
| 0.05 to 0.10 | × | × | × | ✓ | ✓ | ✓ | ✓ |
| 0.10 to 0.25 | × | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| 0.25 to 0.50 | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 0.50 to 1.00 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 1.00 to 1.50 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| > 1.50 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Table 3.11: Desirable Scenario of Integrated Transport System**

innovativeness and performance of the cities' transport systems. It was found that most Indian cities ranked very poorly in this global index as shown in the Table 3.12.

### *3.3.2. Concept of Multi-Modal Transport*

In 1984, the Delhi Development Authority and the Urban Arts Commission came up with a proposal for developing a multi-modal transport system, which would consist of constructing three underground mass rapid transit corridors as well as augmenting the city's existing suburban railway and road transport networks.

| City | Urban Mobility Index |
|---|---|
| Singapore | 1 |
| Stockholm | 2 |
| Amsterdam | 3 |
| Hyderabad | 42 |
| Mumbai | 49 |
| Chennai | 52 |
| Bengaluru | 56 |
| Kolkata | 66 |
| Jaipur | 95 |
| Delhi | 96 |

*(Source: The Economic Times & Arthur D'Little, October 2018)*

**Table 3.12: Urban Mobility Index in Global Cities in 2018**

'Multi-Modal Transport' is a scientific term for something really quite simple; journeys that involve some kind of transfer from one type of travel or 'mode' to another. Even if one is travelling by car or motorcycle for example, a journey is likely to involve a short walk at the start and end points. However, trips by public transport, principally bus and metro, typically involve a longer walk trip to access or egress them and here multi-modality comes into its own. There may also be public transport journeys that involve a combination of more than two transit modes, For example, a walk trip followed by a bus trip, then a metro trip, and finally a cycle-rickshaw trip.

The National Urban Transport Policy (NUTP 2006) provides broad objectives to ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents to jobs, education, recreation and such other needs within cities. The NUTP has the

***Vision:***

► *People centered plans for their common benefit and well-being in our cities*

- *Make our cities the most livable and "engines of economic growth"*
- *Allow our cities to support the main social and economic activities that take place in the city*
- *Encourage growth of urban transport along low carbon path*

***The Objectives of NUTP:***

- *To plan for the people rather than vehicles by providing sustainable mobility and accessibility to all at affordable cost and within reasonable time*
- *This will involve:*

- Incorporating urban transportation as an important parameter
- Equitable allocation of road space with people
- PT should be citywide, safe, seamless, user friendly, reliable and good ambience
- Walk & cycle should become safe modes of UT
- Introducing Intelligent Transport Systems for traffic management
- Road safety and trauma response
- Raising finances through innovative mechanisms
- Establishing institutional mechanisms for enhanced coordination
- Building capacity (institutional and manpower) to plan for sustainable urban transport

One of the methods to achieve such objectives is to "enable the establishment of quality focused multi-modal public transport systems that are well integrated, providing seamless travel across modes". The process of planning and building of multi-modal transport system can be illustrated in Figure 3.27.

It is mentioned in the National Urban Transport Policy (NUTP), that Government of India would encourage building of transport hubs through required financial provisions. These transport hubs should provide seamless inter-change between inter-city or regional and sub-urban services as well as the public transport system of the city. These transport hubs also should have adequate physical space and infrastructural facilities for NMT modes.

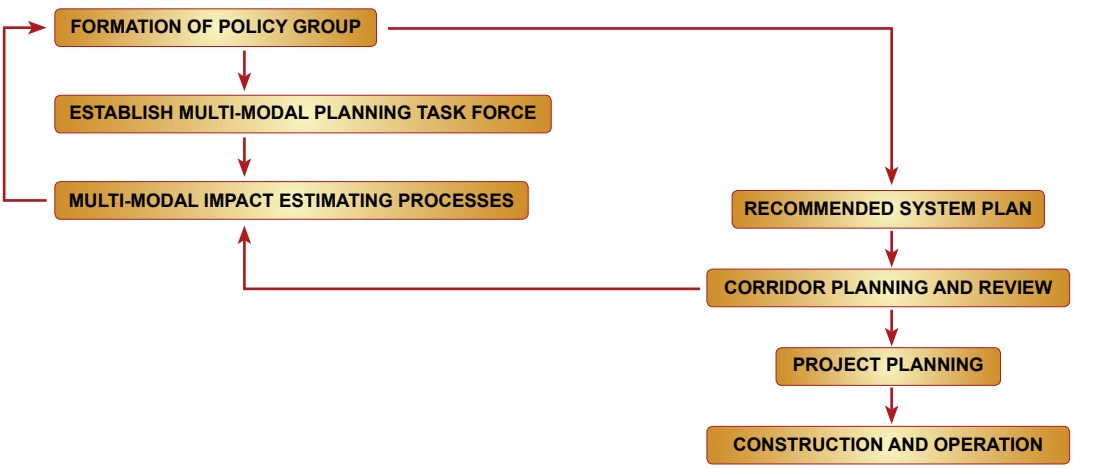



**Figure 3.27: Process of Planning and Building of Multi–modal Transport System**
*(Source: https://www.nbmcw.com/tech-articles/project-management-arbitration/18631-multi-modal-transportation-system.html)*

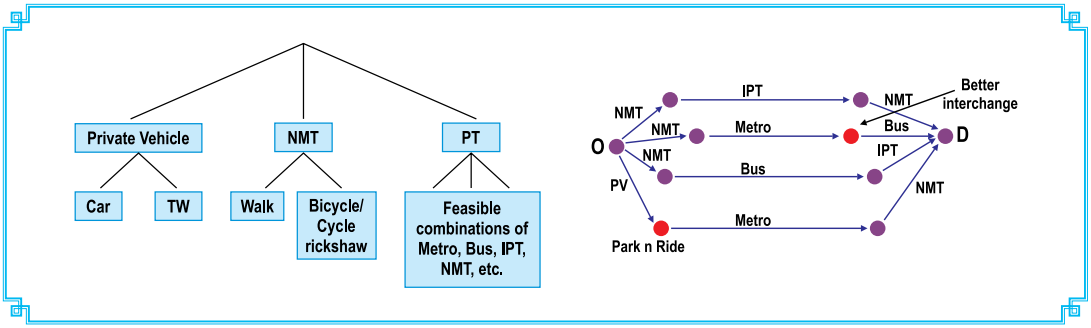



**Figure 3.28: Schematic Diagram of a Multi-modal Integrated Network**

### *Components of Integrated Multi-modal System*

Different modes of transport should be integrated in such a way that they provide the total transport services economically and efficiently to the users. In India, the transport system of urban areas, generally comprise of a number of distinct modes and services, notably public transport (PT), intermediate public transport (IPT), non-motorised transport (NMT), and of course, private modes. Rail based metro, LRT and Mono Rail systems and road based BRT system are developed in many Indian cities based on passenger demand. These trunk-and-feeder mass transit systems are implemented to enhance capacity of public transport system in the city. A trunk route mass transit system has to be supported by feeder service systems using NMT, IPT modes and pedestrian facilities. However, there has not been any effort in developing an integrated and complimenting multi-modal system which includes trunk route modes and feeder service modes. Therefore, the transport systems in all major cities still suffer from major deficiencies including the lack of integration in any practical sense for multi-modal operation. At present, the road based PT and IPT are the dominant modes of transport carrying more than 75% of the total daily traffic, but with absence of any real integration.

A trip is divided into several stages in an integrated multi-modal system. First stage of trip starts from its origin as home to nearest public transit stop/station, where pedestrian, NMT and IPT modes are used depending on its distance. Second stage of trip is generally carried out with trunk route public transit (line haul) system. In third stage, pedestrian, NMT, IPT modes can be used at the terminal end of the trip. Combination of NMT, IPT, personalised vehicle, metro, bus and other public transport modes are used to perform the trips in urban areas. Figure 3.28 presents transport systems with modes and the combination of modes, which can provide a multi-modal environment in trips between origin and destination.

### *Policies, Issues and Gaps*

The National Transport Policy Committee (NTPC, 1980) strongly recommended integrated development of the transport systems taking appropriate advantage of the respective modes, which has never been pursued seriously. It is mentioned in the National Urban Transport Policy (NUTP) that Government of India will support cities to develop city wide integrated multi-modal public transport network. However, facilities required for intermediate public transport modes, viz. parking, pick-up, drop-off spaces etc are not detailed out.

In Section C (vii) (a) of the Metro Policy (2017), it is mentioned that last mile connectivity including pedestrian and NMT facilities within 5 km radius of the metro stations will be essential requirements for availing central assistance for proposed metro railway projects. State governments will commit to provide feeder service system, if central assistance is sought for proposed metro railway system. However, there is no systematic planning and implementation plan to develop the feeder service system in the existing and under construction metro system in at least 10 cities in India. Efficiency of the metro system is compromised due to non-availability of NMT or pedestrian facilities from residences to the public transport stations and regulated IPT facilities from destination station to work place or home. The onus of planning and development of feeder services is on state governments. There is no specific fund for urban transport development in the states, and generally the state governments lack institutional capacity to appreciate and develop efficient multi-modal transport systems with appropriate feeder service systems.

### *3.3.3. Integrated Multi-Modal Transport System*

#### *Need for Integration*

The objective of the integrated multi-modal transport policy is to foster the development of the various transport modes in a manner that will lead to realization of an efficient, sustainable, safe and balanced transport system, where each mode of transport operates in its field of economy and usefulness, with competitive and non-discriminatory prices that are adequate to support progressive development of transport infrastructure and service (Planning Commission, 2001). The broad objectives of the integrated multi-modal transport policy in the context of urban transport could be summarised as follows:

- Meeting the transport demand generated by higher rate of growth
- Capacity augmentation, quality and productivity improvements through technology upgrade and modernisation.
- Increased generation of internal resources and also realisation of optimal inter-modal mix through appropriate pricing and user charges.
- Increase in overall economic efficiency through injection of competitive initiatives in provision of transport services wherever possible.
- Promote sustainable transport system with increased emphasis on safety, energy efficiency, environment conservation and social benefits.

For the effective implementation of an integrated multi-modal transport policy, it is necessary to develop an adequate database systematically, on the traffic volume (patronage) and cost (price) data taking account of perspective technological improvement with due consideration of the impact of fast urbanisation trend. Such data will be extremely valuable for systems of multi-modality to be conceived and implemented both by the public and private sectors.

#### *Requirements for Integration*

In most mega cities of India, the gap between demand and supply of public transport continues to grow unabated. Various studies have indicated potential ridership of public transport in large cities as 60-85% (CRRI, 2001); however, very little planning has been there for realizing it, except in the case of Mumbai, which has a captive ridership of public transport. Most of the urban transport studies have not even aimed for an integrated multi-modal system of all complementary modes, and NMT and walk modes are completely neglected. In addition, the required high capacity systems are not planned nor implemented at right time, and certainly not until the problem goes out of hand.

Trunk and feeder public transport systems were implemented in London and Paris more than 100

years back. The integration with other line haul public transport modes was provided through efficient interchange stations. Table 3.13 shows year of opening of high-capacity metro systems in some of the world cities, including those implemented in Indian cities. Moreover, each of those cities, as shown in Table 3.14, was provided with multiple systems of public transport duly integrated.

| City | Year of Introduction | Population (Million) |
|---|---|---|
| London | 1863 | 2.80 |
| Paris | 1900 | 2.66 |
| Tokyo | 1927 | 2.22 |
| Moscow | 1935 | 3.50 |
| Stockholm | 1950 | 0.45 |
| Kolkata | 1984 | 9.69 |
| Chennai | 1997 | 6.0 |
| Delhi | 2002 | 13.15 |

**Table 3.13: City Size and Introduction of Metro**

In the Indian cities, there are serious bottlenecks due to lack of coordination and integration among the available modes. There is thus an urgent need for serious effort for planned integrated multi-modal transport system giving definite priority in planning and operation to public transport. This is not happening due to the fact that the long-standing demand for Unified Metropolitan Transport Authority (UMTA) has not been fulfilled by creating such an umbrella Authority, which can pursue the real objectives of multi-modal transport in cities. Constitutionally the urban transport being a state subject, UMTA has not been adopted till JnNURM enforced some of these demands on the states. But, there has not been much progress to realize the efficient multi-modal transport, as all the available modes are growing without systematic planning under the guidance of an umbrella agency, which can consider the common interest of all and their complementarities. Therefore, it is imperative that the Government of India consider a legislation in the form of the Urban Transport Act to strengthen UMTA and its implementation in the states.

The World Bank (2002) in its study of transport sector in India found that the deficiencies of the transport system have led to various negative impacts, like:

- Wastage of time and money due to moving people and goods inefficiently
- High opportunity costs of public resources used to maintain or expand infrastructure capacity, or subsidise certain services
- Poor safety outcomes that cause human sufferings, economic loss, and increased inequality

| City | Population in 2000 AD (in Million) | Public Transport System |
|---|---|---|
| Beijing | 10.5 | Bus, Trolleybus, Metro |
| Cairo | 12.0 | Bus, Tramway, Light Rail, Suburban Rail |
| London | 6.3 | Bus, Metro, Surface Rail |
| Moscow | 8.8 | Bus, Trolleybus, Tramway, Metro |
| New York | 7.3 | Bus, Metro |
| Singapore | 2.9 | Bus, Metro, Light Rail |
| Tokyo | 8.0 | Bus, Tramway, Metro, Light Rail, Suburban Rail |

**Table 3.14: World Cities with Multiple Public Transport Systems**

- Adverse environmental impacts (vehicle emissions, inefficient use of non-renewable energy resources, etc.)
- Negative social impacts (displacement of non-motorised transport)

There are many examples of uncoordinated and un-integrated urban transport systems operating in cities across the country. The extreme apathy towards integration of road, rail and other available systems in the cities are especially visible in the last six decades. Till today there is not a single rail-road interchange (even in Mumbai) with all proper and modern facilities. Many cities have excellent prospects of IWT (Inland Water Transport) also, as in case of Kochi, Kolkata, Guwahati, and so on. IWT in specific cases, when integrated with other modes can provide a very economical urban transport service. At present, potential of this mode is not even recognized in most cases in spite of the fact that it is the most energy-efficient, cost effective and environment friendly mode of all available alternative modes. Integrated development of terminal facilities with modern passenger handling and processing systems will open up this mode of transport, which is very promising.

| For the User (Client, Customer, Citizen) |
|---|
| • Lowest cost<br>• Save time<br>• Increase accessibility<br>• Increase safety<br>• Raise production<br>• Increase consumers' benefit and/or profits |
| **For the Supplier (Agency, Firm)** |
| • Fill in service gaps<br>• Lower cost<br>• Make better use of inventory<br>• Increase productivity<br>• Increase sales (use) and services<br>• Obtain desired skills, facilities, expensive technology, etc<br>• Become more powerful in seeking funding<br>• Increase corporate knowledge and wisdom |
| **For Government** |
| • Reduce unnecessary/damaging competition<br>• Increase economic development<br>• Increase tax revenues<br>• Provide greater capacity and flexibility in an emergency |

**Table 3.15: Benefits of Integrated Multi-modal Transport System**

### *Benefits of Integration*

Benefits of an integrated multi-modal transport system are expected to accrue for passengers, supplier firms and government sector agencies as well. Different types of benefits at various entities of the system are shown in Table 3.15 (Dickey, 2002). The potential integration need to be evaluated and negotiated so that it becomes a WIN-WIN situation for all the stakeholders as indicated in Table 3.15.

Transport and logistics for integration are so highly developed in the rest of the world that no country or a city can afford to be left behind. The containerisation of freight transport is one such example, which can not be ignored by even the least developed nation. Integration in multimodal urban transport is required to achieve or create a situation, where a seamless journey for the passenger is possible from an origin to a destination using multiple modes of travel without loss of time or any inconvenience. The modal transfer at the interchange or terminal shall be a coordinated activity with complete logistics pre-planned so as to provide a streamlined flow through the multi-modal system where passengers do not feel the disadvantage of the transfer at all. Thus, in a multi-modal integrated system, every activity from monetary transaction to transfers are fully structured as a part of the system.

### *3.3.4. Methodology of Multi-Modal Integration*

#### *General*

The country has very large number of operating transport systems all over, both at city as well as at regional levels. Integration of various components (available modes) of the transport systems would normally aim to provide a seamless (with automated and/or minimised efforts in transfers) flow of passengers. Integration within and among various transport modes are summarized (Sahai, et. al., 2010) as follows:

1. Physical Integration – Facilitate direct, comfortable and easy access for NMT modes, IPT modes and pedestrian pathways at the public transport stop/stations
2. Fare Integration – Public transport users are required to paythe fare only once for all transport modes/systems required to complete their trip
3. Route Integration – Interchange points are to be facilitated for smooth transfer of passengers from one public transport mode to the other
4. Information Integration – Public transport schedule for all modes need to be available through IT based mobile app and through other information system sources
5. Institutional Integration – Different public transit providers are required to function as part of an integrated unified system and provide links with the various access modes

Practically, the integration is required at all stages of development of such multi-modal system and also in all facets of operation. Integration in planning, operations and management only will give rise to a sustainable system, which will satisfy the requirements of all stakeholders including the travelling public.

#### *Policies and Planning*

Integration starts at the policy planning level itself, and while all policies of the Government had sought it, the road and rail could never use a common planning platform both for the cities as well as in the country context. During the first few decades after independence and later, the road and rail sectors remained in their isolated quarters without any integration in planning. Through appropriate constitutional amendment, the development of high capacity rail based systems has been allowed to be developed by local governments of mega cities. The present developments of metro rails in cities are based on such a model. The normal provision of road network for access to rail and airport terminals in a mega city is not the correct indicator of integration. The deliberate policy for development of various modes should be based on their operating advantages (capacity, speed, etc.) and development costs. The national and local level policies in this context have always been short of what were required from both the Centre and the States. There are many examples where one mode has grown illegitimately and uneconomically at the cost of the other primarily due to the absence of deliberate planning interventions.

The unabated growth of urbanisation and consequent demand for transport at unusual peaks for sub-systems clearly shows a failure of the policy. Planning for transport systems is strictly dependent on the comprehensive and reliable database on the various operational characteristics and performance of the available sub-systems (modes and their technology adoption). Further, in a local level, the transport and land use policies are to be integrated based on social, economic and environmental policy objectives. To manage a policy of integration in multi-modal transport, an authoritative management system with strong

enforcing teeth is required to fulfil all the objectives of such systems. Commensurate to the policy, an investment strategy is also always required to realise the true multi-modal development with integration. Some of the large cities have attempted creating SPV (Special Purpose Vehicle) for this purpose, but those also remained unsuccessful in realizing ultimate objectives of multi-modality option for the urban traveller.

The NUTP 2006 recommended creation of a Unified Metropolitan Transport Authority (UMTA) in all cities with population of ten lakhs or more to facilitate coordinated planning and implementation of urban transport programs and manage integrated multi-modal urban transport systems. It also mentioned that a dedicated Urban Transport Fund (UTF) will be set up along with UMTA. Jaipur, Lucknow, Bhopal, Hyderabad, Kochi, Tiruchirapalli, and Andhra Pradesh Capital Region initiated city specific UMTA and UTF. The main purpose of UMTA is to act as an umbrella body that promotes integrated multi-modal urban transport planning and implementation in urban areas through policy intervention and targeted developments. The dedicated UTF (i.e. the fund) within UMTA will enable the authority to allocate funds to various urban transport projects; and it will provide UMTA with financial strength to undertake activities to achieve its objective. The objectives of UTF will be to identify innovative dedicated and sustainable funding sources, efficient management of funds etc. UMTA bill needs to be passed through legislative assembly and it is required to be converted to an UMTA Act as per the provision of laws of the state governments. However, UMTA and UTF in various cities in India are still in their nascent stage and need political and administrative push for implementation. Following policies can be included for development of integrated multi-modal transport system in cities:

- Trunk line public transport projects are to be evaluated along with access and egress mode of projects based on a comprehensive mobility study, which emphasises movement of people from their home to work (origin to destination) and such other travel.
- All modes of trunk-and-feeder public transport, e.g. Metro, LRT, BRT, Mono Rail, etc are to be evaluated in a travel demand model of a city along with access modes, to provide true choice of public transport modes to the urban population residing in the city.
- Regularize/formalise Intermediate Public Transport (IPT) modes such as auto rickshaws, cycle rickshaws, e-rickshaws, etc. through use of GPS vehicle tracking system and organized operation, with real time connectivity with UMTA and with unified Command and Control Centre. Scheduling of IPT for each route, fixation of fare, unified ticketing system, smart card system, etc. are other elements, which will ensure reliability and efficiency. The app based IPT systems such as taxis, autos, two-wheelers, etc. might be considered in implementing multi-modal transport.
- ULB and state government need to provide adequate parking space for all IPT modes, pick-up and drop-off bays, pedestrian facilities, EV charging facility, disabled friendly space adjacent to each of the public transit stations, e.g. Metro/BRT/LRT etc. depending on the level of demand.
- Public Bike Sharing (PBS) system to be promoted at cities along with city wide cycle/ NMT (network) lane facilities, where bikes can be parked near to the public transport stations/ stops and at the educational institutions, and office establishments. Unified smart card also may be adopted for all modes, which may include bike use charges based on duration of use.

Development of multi-modal interchange hub is also required to be part of integrated transport system development policy. Multi-modal

transport infrastructures are generally supposed to be traveller friendly, and therefore, these proposed places could be trunk line terminals or intermediate station locations that have significant economic activities. Public transport nodes cater for heavy passenger movements to the concentrated economic activities, and hence qualify as the sustainable mode of travel to serve these highly concentrated economic activities, and are logically appropriate candidate for multi-modal hubs.

A well-integrated and coordinated public transport system would require considerable network level initiatives for multi-modality for providing seamless travel experience equivalent of a personalised mode discounting the merit and need of such personalised travel modes. However, research indicates that considerable benefits can be achieved with minimal interventions for integrating the public transport routes by creating the interchange hubs. While the vehicle hours travelled (VHT) in the network and passenger travel time will drastically reduce due to increased connectivity and seamless travel opportunities, the public transport terminals can be multi-modal hubs by making them highly accessible and connected through planned interventions, such as,

- Improving first/last mile connectivity; and
- Rationalized public transport routes, i.e. services and frequency.
- The multi-modal transport infrastructures will have to be specially developed considering the need of the users, which may include,
  - Parking for different categories of personalised modes (car, motorcycle, bicycle, etc.)
  - Food courts for utilising transfer time for quick services
  - IPT (auto, taxi, hired bicycle, etc.) stand

Multi-modal hub development requires large space in the heart of the city to accommodate passengers during peak hours and it needs a huge investment. Therefore, developments through Public Private Partnerships (PPP) model, or other innovative techniques for financing multi-modal hub are to be encouraged by the state government. Many commercial uses are compatible with multi-modal interchange/ transfer area, where passenger footfall is huge and development of multi-modal hub projects in such locations can fetch satisfactory return of investment to the private investors. PPP model for operation and maintenance of multi-modal hub are also to be included in the project development process. Key Performance Indicators (KPIs) and benchmarks for Integrated Multi-modal transport should be established, which are to be aimed at every development in the urban transport in the country.

### *Operational Integration*

The operational integration requires several key aspects to be coordinated for the multi-modal journeys to be unaffected by transfers and to provide comfortable door-to-door service to the customers. These are generally:

- Fare policy and sharing
- Ticketing and reservations
- Schedule integration (linking operations)
- Commercial promotion
- Sharing of terminals/interchanges
- Sharing of routes in the network
- Information sharing

Most of these can also be called as components of service integration and are required to provide the best and most comfortable journey to the customer comparable to private modes. However, the country has not seen much in this direction unless there is some physical compulsion as in Mumbai urban transport case. The Indian Railways (Suburban services of Western Railway

and Central Railway) and BEST (Bombay Electric Supply and Transport Undertaking) seem to be in some coordination, but far short of true integration. Even with that minimum level of coordination both rail and bus together cater for 88% of daily urban travel demand in Mumbai.

In a contrast, the Ring Railway in Delhi (developed and operated during Asiad 1982) failed miserably in the absence of operational integration between Indian Railways (Northern Railway) and DTC (Delhi Transport Corporation). Land use has been cited as the cause of this failure of the Ring Railway without admission of the fact that no mass transport system is expected to provide door-to-door service. The inability to integrate the complementary modes has never been shown as the reason of this failure at any time.

### *Infrastructure Accessibility*

Efficient multi-modal integration of various modes such as walking, bicycles, and other NMT modes, along with integrated systems of parking, feeder system, and land-use and communities around the public transport system will be other key elements to an effective multi-modal system. This process will include:

- Improvement of walk ability from neighbouring areas to public transport stations along the corridors by providing continuous and reasonably good walkways, safe crossing, etc.
- Developing network of bikeways (exclusive and mixed), bike-share scheme, etc. to provide alternative modes to access public transport modes
- Integrating NMT and other modes by providing suitable proximate spaces for pickup and drop off areas for IPT, cycle rickshaws, feeder bus system, etc.

In summary, the elements of connectivity and accessibility that enable an effective multi-modal transport system are:

- Proximity – a balance of proximity to related land uses and to other diverse activities (mixed use) gives people reasons to walk
- Interaction – a range of opportunities for interaction, formal and informal, in a network of intersecting paths and gathering spaces allows incidental conversations and connections to occur
- Quality – a network of places and links that look good, safe, and comfortable encourages people to walk (Australian Policy Online, 2014)

Incidentally Transit Oriented Development (TOD) concept requires a systematic planning of the multi-modal access provisions in support of the transit lines with the objectives of appropriate infrastructure development for ease of access.

### *Management and Regulations*

To achieve better output from any such modern or integrated system, we must be able to abolish all unproductive factors like uneven taxes and unofficial hafta collected by opportunist Organisations (in the disguise of enforcement), which contribute to inefficiency. In the de-regulated/ liberalised environment also many organisations have not yet abandoned their colonial culture/ attitude of control and regulation for a coordinated operation. Multiplicity of authorities, with overlapping and vague functions and powers, also enable them to destroy the basic ethos of integrated multi-modal system of seamless transport.

The protected environment is supposed to have been over. The globalisation has brought down the tariff barriers, and services of highest quality can only survive in the competition. In such new economic order, to attract customers the business is reduced to marketing and innovation. Thus, only an integrated multi-modal system can meet the high standard and customer requirements; but there are possibilities of unfair competition or

even monopoly. Then, onus should be on each individual groups of operators of each mode to provide services totally integrated to the overall system, which is supposed to be controlled by the unified regulator. If anyone found to be operating in non-integrated fashion, the license be withdrawn by the regulator through proper review. Therefore, a Central Regulatory Authority (such as UMTA) should oversee the entire planning and operation of the multi-modal system (for complementarity and compatibility) to control the legitimate developments as well as quality and quantity to be served to the customers.

### *Technology Policies*

The unprecedented influence of technology in twentieth century has not left any sector untouched. Transport being a phenomenon where separation by space is to be overcome in an efficient way, technology has always been a partner. Today's transport vehicle/unit has very small component of its total system as the internal combustion engine or electric motor, etc; and much more is in the form of electronics and telemetry to make the vehicle integrated to the total system of multiple modes. The innovations in the logistics of transport process through multiple modes involving transfers of passengers are truly intriguing experiences of integration. In addition, both transport network (whether rail, road, sea or air networks) and vehicle units are made extremely intelligent to provide utmost comfort, safety and confidence during travel. For example, an airliner provides today all the office facilities including telephone, television, internet and relaxation facilities on board, and these are gradually being made available in urban transport modes. ITS (Intelligent Transport System) has revolutionised the transport industry across the world. Within the first quarter of this century, ITS developments and GPS based vehicle tracking system has already facilitated complete integration of even an entire country's transport system leaving nothing as unknown at any point in time and space on real time basis. Examples of such integration are already available in many transport sub-systems of various countries in Europe (Rat, 2002). The emphasis will have to shift from merely providing transport infrastructure and services to technological upgrade and modernisation of the same in order to ensure better mobility through multi-modality and not only just accessibility.

Government of India is expected to make an investment of ₹ 2 lakh crore in smart city mission and 9.5% of the smart city mission funding is allocated for IT/ICT solutions, where majority of the funding is expected to be spent to develop Integrated Traffic Management System (ITMS) and city surveillance system in the 99 smart cities in India. Various types of cameras and sensing devices will be installed in strategic locations of the city's transport network and the ITMS system will be controlled through Integrated Command and Control Centre (ICCC). Multi-modal interchange or transfer points (the hubs) are required to be monitored for efficient operations of different constituent modes in the system.

### *Funding Sources*

Funding requirement for mass transit system is much higher compared to the funding requirement for IPT and NMT infrastructure required for efficient first and last mile connectivity. The main trunk line public transport system is generally funded by central government or through SPV by borrowing from equity market etc. However, the major part of state government funds can be utilized developing the IPT and NMT infrastructure for access/egress modes to develop an integrated multi-modal transport system. Private funding can also be attracted through PPP mode, while other innovative financing models can also be encouraged, e.g. land value capture and municipal bonds, etc.

National, state and local government can apply to multi-lateral funding agencies for urban transport projects and national government can contribute to the funding gap and establish link between international and national funding mechanism. Climate Change Funds can be used to develop sustainable urban transport infrastructure, which has not been utilised to its full potential. Only 28 projects for urban transport development were applied out of 6,660 projects submitted to avail CDM fund up to 2013 (Mahendra, et. al., 2013). Japan International Cooperation Agency (JICA) Climate Finance Impact Tool (JICA Climate- FIT) fund is available for the urban transport projects where reduction in GHG emission and reducing vulnerability of climate change are established (JICA, 2011).

Public Private Partnership (PPP) can be utilized in development of urban transport project, where social, environmental, macro-economic and political risks can be assumed by the public sector, and private sector can utilise their skills in assuming financing risk, as well as construction and commercial risks. Strong legal, institutional and procurement framework, with appropriate regulations, incentives and accountability are to be developed at each level of government to capture private sector investments (Embarq India, 2013). Private investment in India and Thailand are considerably high, e.g Indian private sector investments in port is 80%, airport 64%, road 16% and rail 4% (MGI, 2013). Private investment in urban transport projects can be increased with positive efforts from government side to create favourable environment for private investors to invest at national, state and local level, but with definite overseeing by a Regulatory Authority.

***Summary***

Some of the major economic and environmental benefits of development of multi-modal transport system for urban areas are as follows:

- Economic benefit of non-use of private vehicles will include less consumption of fuel, saving in travel time and travel cost
- Decongestion of city roads due to reduction of private car use. Also, shifting of major land uses to satellite locations with better transport facilities
- Generate formal employment through regularisation/formalisation of IPT and NMT modes
- Use of public transport by majority will reduce quantum of polluting gas emission from private vehicles, which will be a positive impact on environment
- Increased supply of commercial spaces in multi-modal interchange hub in the transit line
- Promotion of e-rickshaws and integration of Public Bike Sharing with the multi-modal system will further reduce carbon emission

A past study (TERI, 2007) on public transport and integrated multi-modal transport planning revealed some valuable outcomes of the multi-modal transport. A few of the major findings were:

1. There will be an 18% reduction in motor fuel demand, if buses meet 70% of the total passenger travel demand in 2030.
2. If fuel efficiency of vehicles can be improved by 5% and 20% in 2015 and 2030, respectively, for the vehicles registered after 2010, a reduction of about 17% is achievable in fuel consumption by 2030 as against the Business as usual (BAU) scenario.
3. Integrated land-use and transport planning can also reduce transport energy demand by 20% by 2030.

### *3.3.5. Dedicated Nodal Authority for Multi-Modal Urban Transport*

As per the National Urban Transport Policy (NUTP) 2006, the large metropolitan cities with population in excess of one million were to set

up the 'Unified Metropolitan Transport Authority' (UMTA). As per the NUTP, UMTA should not report to the Secretary of Urban Transport in the State Government, but to the Metropolitan Planning Committee (MPC)/District Planning Committee (DPC). But, UMTAs created till date report to Development Authorities, and therefore, the current UMTAs act more like advisory committees and not as empowered technical decision making and coordinating bodies.

The UMTA should undertake all work related to urban mobility in the city. This will include:

- Strategic and Policy Functions;
- Regulatory Functions;
- Integrated Planning;
- Travel Demand Management;
- Organising Services;
- Providing Common Services;
- Resolution of day-to-day matters and monitoring the work assigned to implementing agencies both for the city and the surrounding region.

For UMTA to be effective it should be backed by legislation and the entire funding for urban transport should be routed through UMTA. All one million plus cities should have an UMTA and this should be incorporated in an inter-municipal cooperative manner. In large five million plus cities, the UMTA should host its own counterpart to the Office of Transport Strategy (OTS), which would be a dedicated technical strategy team looking at future plans and responsible for analyzing alternative project possibilities and technologies and then undertaking a broad-based consultation exercise to inform decision makers on the options. This function of the OTS could be centralized at the state level for other million plus and smaller cities in the state. UMTA should either report to the MPC/DPC or to an inter-municipal cooperative arrangement created by the urban local bodies involved. A few logical functions of UMTA can be enlisted as follows:

1. UMTA should initiate and fund the studies and prepare common plans, while its member agencies raise funds to improve their respective infrastructure and services.
2. It should develop a parking policy based on market based pricing.
3. UMTA should advise and help implement benchmarks, standards, processes and other tools to make transport more sustainable and modern.
4. UMTA should also explore formal and informal tie-ups with international sister Organisations who have considerable expertise and experience in managing urban, citywide transport systems.

As part of its efforts to improve pedestrian facilities on roads, UMTA should initiate re-design studies of all major roads in the city. Additional facilities for easy access to all citizens, including disabled and elderly should be incorporated into the design.

Having established a UMTA, a city would now have to look at the most efficient ways to induce the modal shift from personal transport to various forms of multi-modal transport. Travel demand management (TDM) is a slew of measures that aim to induce commuters to public transport, ridesharing, walking, bicycling, teleworking, etc and cause mode shift from personal transport. TDM is one significant method of managing modal balance in a city for different objectives, which is detailed in a separate heading here.

### *International Case Studies Similar To UMTA*

**(a) Land Transport Authority –Singapore**

Singapore, with its land constraints and high use of public transport, gives a classic example of a well-executed plan for integrated transport. This is enabled by the Land Transport Authority (LTA) which was established in 1995 with the merger

of four public sector entities including Registry of Vehicles, Mass Rapid Transit Corporation, Public Works Department and Land Transportation Division of the Ministry of Communications. It is a statutory board under the Ministry of Transport, which heads land transport developments in Singapore. It is the agency responsible for planning, designing, building and maintaining Singapore's land transport infrastructure and systems. The objectives of the Land Transport Authority are:

- To make the land transport network integrated, efficient, cost effective and sustainable to meet Singapore's transport needs
- To support a quality environment while making optimal use of our transport resources and safeguarding the well-being of the travelling public
- To develop and implement policies to encourage commuters to choose the most appropriate transport mode.

It uses technology to strengthen public transport infrastructure. This includes a portal "Mytrasport.sg" which provides traveller information systems for seamless planning of commutes throughout the region as shown in Figure 3.29.

The impact of this nodal authority is that nearly 80% of trips (4.24 million) in Singapore are performed on Public Transport comprising of bus, MRT, LRT, and Taxis. The supply of public transport per capita is one of the highest in the world, due to which there is high usage of public transport, which coupled with travel demand restraint measures, like area licensing system, vehicle quota system, congestion pricing etc. has resulted in decreasing registration of private cars.

**(b) Unified Transport Authority-London**

The Greater London Authority is a unitary authority headed by a directly elected mayor. It is responsible for a number of functions including transport, policing, fire and emergency planning, economic development, land use planning, culture, environment, and health. Within the transport sector the Mayor is responsible not only for public transport but also for the major road system and for traffic management and parking policy. By combining these functions he is able to formulate transport policy on a comprehensive and strategic basis, integrating the traffic and public transport functions and determining the priorities for expenditure in the sector. The Mayor sets bus, underground and taxi fares,

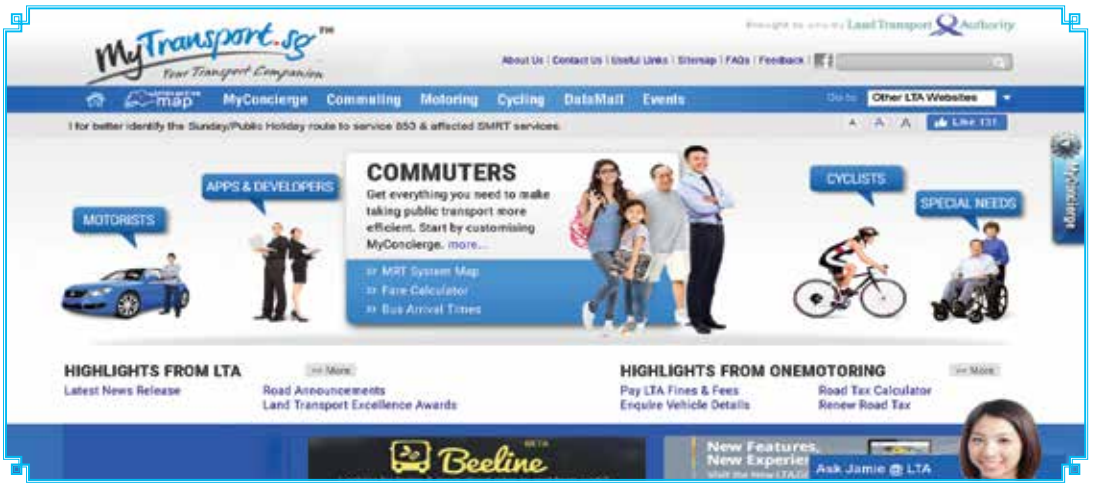



**Figure 3.29: LTA Portal** *(Source: Mytransport.sg)*

and determines how much money is available for procuring tendered services. He might thus be regarded as a one-man elected Transport Authority. The Mayor obtains funds partly from transfers from the central government, partly from local taxation and partly from the congestion charges or road-pricing scheme.

While key strategic powers rest with the Mayor, operational responsibility lies with Transport for London (TfL), which is accountable to the Mayor and responsible for delivering an integrated and sustainable 'Mayor's Transport Strategy'. Transport for London (TfL) was created in 2000 by the Greater London Authority Act 1999. The strategy covers all modes for which TfL has responsibility including buses, metro, roads, walking, cycling, freight and water transport. Although not responsible for sub-urban rail, the strategy promotes a policy of partnership with the responsible agency.

In addition to the strategy, Transport for London (TfL) is responsible for:

1. Managing the 580 km network of major roads termed the Transport for London Road Network (TLRN)
2. Managing/operating/owning all traffic signals (about 4800 installations)
3. Managing London Buses through London Bus Services Ltd. which regulates the services (provided by over some 3730 km of bus routes), contracts the routes to the private sector (operating some 7000+ buses); TfL provides and owns infrastructure (stops, terminals) and finances on-road bus priority (currently 1000 sections of bus lanes totalling more than 240 km) on both its own TLRN roads and Borough (2nd tier authority) roads.
4. Managing London Underground (the metro system)
5. Managing/operating/owning some lesser public transport services such as London River Services, Trams (28 km) and Docklands Light Rail (26 km).

### *3.3.6. Summary*

The personalised modes of transport have witnessed tremendous growth in the last two decades and contributed to the development process in the country. It is necessary to formulate an integrated transport policy to ensure adequate, efficient and high quality of transport services, which will enable commuters to shift away from the personalised modes. Planned development of multi-modal systems with integrated IPT, NMT and pedestrian access facilities for all public transport modes available in the cities are the major challenges, where state government can play a vital role. Implementation and functioning of UMTA and UTF for their true objectives can facilitate much needed institutional reform and integration in urban transport development. UMTA/UTF can formally plan for the multi-modal transport environment, duly exercising their unifying authority, and recognising multi-modality possible in different environment of urban space. The states have to enact and empower the UMTA to be in the saddle with complete legal backing, even for the on-going implementation of 99 smart cities across the country.

IT/ICT applications can play a pivotal role in providing a multi-modal transport system through a central command and control centre for ensuring the quality and quantity of services in the system. The investment that will be required to develop the urban transport, as integrated multi-modal systems, will pay for itself in a short time. The currently pursued philosophy of privatisation in transport sector can be used to achieve this in the shortest possible time, but must not be in piece-meal approach and should be a guided development of multi-modal system. Thus, integrated multi-modal urban transport system in large cities can provide convenient, efficient, safe and environmentally benign urban transport.

Moreover, a reliable IT enabled urban transport will ensure a smart growth of these cities.

The present public transport sector has significant shortfall to cover in terms of provision of quality and affordable services to the public. Currently, it appears that in addition to the government and organised segment, there is a proliferation of the unorganised segment of the various forms of IPTs and personal modes to cater to the demand as seen by the significant growth of sales of cars, 2-Wheelers and taxi aggregators. However, the opportunity is now available to leap frog the development of the sector through deployment of new technologies in transport and IT as well as revenue mobilisation using innovative means. The creation of a nodal agency for management of multi-modal transport like UMTA in a city and empowering the agency with administrative powers and technical manpower as well as financial support shall turn out pivotal for transforming urban transport scenario in the country. With the right enabling environment and proper structuring, private sector investment, innovation and efficiency can be brought onto a common platform to plug gaps in service delivery. The opportunity is now to make the cities more mobile, enhance the infrastructure of our public transport and boost its customer experience.

Propelled by global mega trends, public transport is witnessing transformational changes across the world, and India is no exception. In the past two decades, India has witnessed rapid development of Metro Rail, Highway Infrastructure, Bus Rapid Transit Systems, ride hailing services and many such other innovations that mark a march towards modernity. Yet there are deep deficits in the provisions of public transport services in India with inter-modal integration largely non-existent. First mile and last mile connectivity challenges deprive the commuters of a seamless travel experience. For sustainable development, a paradigm change in terms of multi-modal integration of public transport facilities and Non-Motorized Transport (NMT) infrastructure is essential. A consensus is required for development of a 'Unified Metropolitan Transport Authority' (UMTA) for all million plus cities of India which should be empowered to make technical decisions and must act as a Nodal Authority directing all stakeholders towards achieving a common goal for seamless mobility by multi-modal integration. This approach would lead to development of an integrated multi-modal transport system as a way to enable modal shift and reduce the dependency on private vehicles in Indian cities.

## 3.4. Parking Policy

### *3.4.1. Background*

Rapid motorisation and lack of sufficient space are one of the major factors to influence the mobility and accessibility in a city. As a result, demand for infrastructural facilities for parking is increasing. In particular locations of the urban areas, total number of motor vehicles exceeding the total number of heads per family, the parking scenario is woefully falling short of the current requirements. Tremendous pressure on parking spaces leading to a serious concern on traffic congestion, accidents, unequal demand and supply ratio, environmental hazards etc. There is a need to focus on the common issues and challenges faced by the parking sector in major cities as well as medium sized cities. The parking policy needs to be structured in such a way that these issues are tackled effectively.

As per some rough estimates, a car runs only for 400 hours on an average in a year, and is parked the rest of the time (8,360 hours or 95 per cent). This is reflected in the enormous demand for urban land for parking. Parking encroachment (in terms of on-street parking) on public spaces and walkways compromise use of sustainable modes namely bicycles, pedestrians etc. Parking takes away safe walking space from people and redoubles unsafe conditions on the carriageway. It not only converts short-

distance zero-emission walking trips to motorised trips, but also undermines the utility of bus and metro systems, as safe access to these modes get compromised. According to the 2016 Handbook of Urban Statistics of Ministry of Urban Development, Indian parking fees are lowest in the world. Even in expensive parking structures, parking rates are minimal and not adequate to recover the cost of investment. This cheap and free parking is a subsidy to rich car owners and loss to the nation. This subsidy amount will work out to be much larger if the rental or land cost is taken into account. Increased investment in expensive and prime areas for parking further enhances this subsidy as parking rates are not expected to recover this cost. This also implies that urban local bodies have failed to garner enough revenue from parking to invest in local area improvements. Parking demand is market-driven and its price should also be determined by the market.

Parking pressures degrade quality of life in residential neighbourhoods which has already scarce land area. As car ownership increasing on a mass scale, the residential neighbourhoods will never be able to provide adequate parking. Consequently, parking pressure will force encroachment of green areas and playgrounds, and block access to houses, bus stops, market places etc. Parking on roads or footpaths also blocks access of emergency vehicles like ambulances, fire trucks and police to homes, offices and buildings. It also affects severely safe walking and cycling by elderly people, children and disabled people within the residential neighbourhoods. Unorganised and free parking can lead to law and order problems.

Thus, the absence of proper parking policies can take away land from housing for the poor and community infrastructure such as schools, healthcare centres, and old age homes and so on. Increasingly, higher share of public land is being diverted to meet the parking need of car owners, who are a minority. This has also led to the neglect of parking requirements by public transport buses, para-transit and bicycles in public spaces.

An average compact sedan is about 5.75 feet wide, while the average height is slightly less than 5 feet. A sedan's length averages just more than 17 feet (518.16 cm). A car's parking space equates to the real estate market value of ₹ 2.5 lakh on an average, in cities. Local municipal bodies are denied of this amount as the parking space is freely enjoyed by vehicle owners and shop owners. If we assume that the unauthorized parking of cars would be around 30 km, then the total real estate value of unauthorized parking belt would be around ₹ 289 crore. That's a huge economic loss to local municipality. This calculation does not take into account losses due to traffic delays, additional fuel consumption etc. To understand the loss in perspective, assume an annual rental of 10% of real estate market value then the Municipal body forgoes a hefty amount of more than ₹ 28 crore as annual rental revenue. This small chunk of additional revenue will definitely help the municipal body in multiple ways (Outlook, 2016).

The ineffective implementation and improper parking policies by the authorities would lead to deterioration of the traffic and increase space congestion woes across the country, especially cities. On the contrary, better parking policies will help the authorities to overcome these traffic and space congestion problems.

### *3.4.2. Types of Parking Facilities*

Parking facilities can thus in a major way be divided into two types: On-street and Off-street. These can be indoor and outdoor, public or private. It can be a parking garage, or a parking space that belongs to the property of a person's house. The different types of parking facilities are given below:

### *Parking Lot*

A parking lot is an area that is assigned for parking. Normally, the parking spaces are marked on the ground with white or yellow lines that form squares,each of which fit one car.

### *Parking Garages*

A parking garage is also called car park, parking structure, parking building, parking ramp or parking deck. There are several types of parking garages:

**(a) Single level parking garage**

A single level parking garage is a parking garage that has only one floor.

**(b) Multilevel or multi-storey parking garage**

Multilevel or multi-storey parking garages are parking garages that have multiple floors to park at. The design of a multilevel parking garage can be very different. The most common design is a garage with ramps to move from one level to another. Parking garages that also use lifts to go from level to level with manual operations. There can also be parking garages with robotic systems that move cars from one level to another. The floors of the parking garage can either go up, down or both.

**(c) Underground parking garage**

An underground parking garage has levels below the surface. Most often underground parking garages are located in city centres and malls, where there's not much space available to build a parking facility.

**(d) Automated parking garage**

This is a multilevel parking facility with an Automated Parking System (APS). The automated parking system will move a car to the available parking space somewhere in the tower. The cars can be moved vertically and horizontally with the use of hydraulic or mechanical lifts. The benefit of a multilevel parking facility with an automated parking system is that more cars can be accommodated in a compact space because the cars are parked by robots, and, no one needs to get in or out of the vehicle.

**(e) Semi-Automated Parking System**

A Semi-Automated Parking System uses a mechanical system to move cars to their parking space. However, it needs a human action to work, either by the driver or an attendant. This action can be as simple as pushing a button.

Typical examples of different parking facilities are shown in Figure 3.30 (a) to (f).

### *Car Ports*

A car port is a covered structure where one or more cars can be parked. Car ports are usually located on people's driveways next to their house. These are private property that comes with the house. Car ports do not have four walls: Normally they only have one or two walls and sometimes they are attached to a wall of the house it belongs to. Car ports offer limited protection from bad weather conditions like rain and snow.

### *Parking Spaces on the Side of the Street/ Roads*

The spaces that are laid out for the use of parking on the side of the road, where that can be charged or be free, are considered as parking facilities. This usually only happens in residential areas where it isn't crowded.

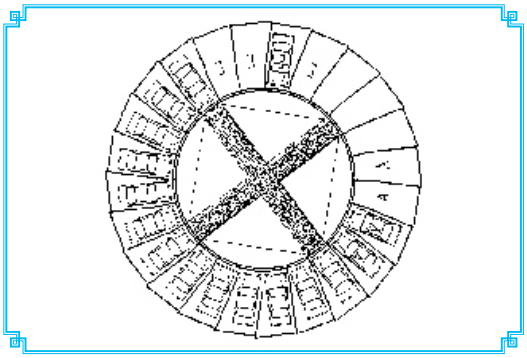
## *3.4.3. Existing Parking Norms and Capacities of Different Parking Facilities*

It has been established that large car parks will operate efficiently only if they have appropriately planned and designed entry and exit points so that the facility can be adequately serviced in the peak period of the car park. Since there is not

(a) Example of Multi-Storey Parking System

(b) Example of On-Ground Parking Lot

(c) Example of Automated Parking System



(d) Example of Rotation Mechanism

(e) Example of Automated Parking System (Car Stacker) in Chennai

**Figure 3.30: Typical Examples of Different Types of Parking Facilities**

(f) Example of Automated Parking System (Car Stacker) in Italy

much researched data available, approximate maximum lane capacities are given in Table 3.16, for comparison purpose to understand the role of different parking facilities.

### *Existing Parking Norms in India*

For achieving effective and efficient management of traffic in the congested areas, the parking

| Entry point (vehicles/hour/lane) | Exit point (vehicles/hour/lane) |
|---|---|
| Free flow - 600 | Free flow - 600 |
| Semi-Automatic/ Card Reader - 400 | Ticket or token acceptance unit and boom gate - 300 |
| Automatic ticket issue and boom gate - 300 | Cashier controlled - 200 to 250 |
| Manually controlled - 250 | |

Table 3.16: Approximate Maximum Lane Parking Capacities

| S. No. | Type of Land Use | Use Premises | Permissible Equivalent Car Spaces (ECS) per 100 m2 of floor area |
|---|---|---|---|
| 1. | Residential | Residential Group Housing | 2.0 |
| | | Cluster Court Housing | 2.0 |
| | | Plotted Housing (Plots above 165 sq.m.) | 2.0 |
| 2. | Commercial | Retail Shopping, General Business and Commerce | 2.0 - 2.4 |
| | | Wholesale, Warehousing, Cold Storage and Oil Depots | 3.0 |
| | | Hotels, Banquet Halls, Community Halls | 2.0 |
| | | Mixed Land use | 2.0 |
| 3. | Manufacturing | Manufacturing and Service Industry | 2.0 |
| | | Flatted Group Industry | 2.0 |
| 4. | Government | Government Offices | 1.8 |
| 5. | Public and Semi Public facilities | Nursing Homes, Hospitals | 2.0 |
| | | Government Hospitals | 2.0 |
| | | Education and Research-College, University and Public Schools | 1.33 |
| | | Socio Cultural, Distributive and other Community Facility Centres | 1.8 |
| | | Communication-Post / Telegraph / Telephone Centres | 1.33 |
| | | Religious Centres | 1.33 |
| 6. | Other Essential Services | Police Station / Fire Station / Disaster Management Center | 1.33 |

*Source: Parking norms established by DDA (as per Delhi Master Plan - 2021)*

**Table 3.17: Norms Specified for Urban Area under Indian Conditions**

requirements have to be met appropriately. The norms specified for urban area under Indian conditions are given in Table 3.17.

### 3.4.4. Intelligent Transport Systems (ITS) in Parking Facilities

ITS is the application of computer technology where it gathers data about the transport system, processes it, and then uses the processed data to improve the management of the transport system, and/or to provide the transport users with more and better information on which to base their transport decisions. ITS can help transport planners to achieve policy objectives in many different ways. It can help to tackle congestion, pollution, poor accessibility and even social exclusion. It can also help to reduce journey times and improve reliability – either in actuality, or simply by changing people's perceptions. And it can improve the efficiency with which transport systems function. In certain circumstances – for example, Advance Parking Management System (APMS) and Parking Guidance Systems – it can help to reduce parking search time bringing overall benefit to the society. Sophisticated booking and scheduling software can help to maximise parking space utilisation. Such APMS can be promoted in PPP (Public Private Partnership) mode as there is going to be huge initial investments involved and of course, the recovery can always be made from the benefits generated after implementation.

The benefits of APMS are given below:

- Reduction in travel time, fuel consumed and emissions while searching for available parking space
- Better use of parking capacity due to real-time counting and guidance.
- Efficient circulation due to guidance of vehicles directly to vacant floor or area
- Higher revenues for the parking facilities
- Higher customer satisfaction

#### *Indian Context*

Some of the ITS technologies implemented in Indian context are given below:

- ITS technologies for improving road safety in India has been confined only to infrastructure based technologies
- ITS technologies like ETC deployed on selected sections of highways and expressways
- Variable Message Signs (VMS) for giving advance information to motorists and improving safety
- Area Traffic Control (ATC) system for effective traffic management in city centers
- Installation of online GPS system on public transport
- Installation of APMS at various congested place and city centers (e.g. APMS installed in the city of Delhi at Palika Bazaar, Connaught Place, High Court, Sarojini Nagar and NDMC) and the details are given in Chapter 4

### 3.4.5. Elements of Parking Policy

The following points need to be considered to formulate an appropriate parking policy for the cities:

- Parking of a vehicle is necessary because of the nature of the trip, however, the required parking facilities need to be created and infrastructure has to be in place in order to appropriately charge for parking of the vehicles. A uniform guideline should be considered to develop parking facility for every commercial activity. Before opening any commercial or public dealing related activity, the parking demand needs to be assessed and accordingly the parking infrastructure should be provided
- The policy should also not allow parking of any vehicle on the main road or in front of the houses by the owner of the house and strict implementation of this policy with the help

of enforcement agencies and appropriate monitoring systems need to be considered

- In addition to this, the other ways to solve parking issues, are by providing facilities such as multi-level car parking. The multi-level car parking can be of two types – conventional and automated. Conventional multi-level car parking can be done overground or underground. The open parking areas are preferred and are safer compared to closed areas; wherein the parking has to include specialised fire protection systems and mechanical ventilation
- Intelligent Transport System (ITS) technology namely advance information system, parking meters and mobile parking apps can be an effective way to solve parking issues at the city level
- The parking policy sometimes is implemented in megacities as a measure to restrict vehicle usage restriction, by appropriating parking charges according to location and timing. For example higher parking charges for certain commercial areas and timings can be levied to improve the traffic conditions in those areas. Though such dynamic parking charges or increased parking charges will certainly influence and restrict the vehicular entry into those areas, they are not the only criteria to solve parking issues at a city level. If the appropriate parking facilities are not available surrounding the Parking Charging Area, then that area becomes more congested. Considering this, the parking policy has to be prepared for the entire area holistically
- Necessity of parking permit before buying a new car as well as used (second hand) car. The parking space needs to be shown in order to register a vehicle in the name of buyer which is mandatory in many developed countries
- Parking for mixed land uses should be included with the residential, commercial, official, institutional and hospital land uses. Parking share by customers, retailers, residents in mixed land use areas should be included. Parking pattern can be analysed for customers, employees, visitors considering different land uses
- Parking regulations based on some key elements in terms of ownership, user category, and, parking time limit should be incorporated in the policy. Fair and equitable management and enforcement should be considered
- Parking Policy should include guiding principles, parking planning, staff deployment, training, Safety, Security & Risk Management, financial reporting and planning, strategic parking management, operational efficiency, maintenance programs, effective use of technology, parking system marketing, Parking Enforcement, Parking & Transportation Demand Management and Competitive Environment
- Basic parking elements for instance infrastructure, pricing and regulations should be mentioned in the parking policy. Parking Marketing and promotion need to be introduced

## 3.5. Sustainable Urban Transport

### *3.5.1. Background*

With the increase in population, transport demand in terms of private vehicles is continuously increasing in our cities with a growth rate of about 12% per annum. As the city size increases, the share of the public transport is supposed to increase and the share of private transport modes (namely car, two wheelers etc.) should reduce for balanced mobility in the urban area. However, there is always mismatch between supply and demand of transport, causing unbalanced modal splits. Because of that, private vehicle share is continuously increasing and public transport share is decreasing as the city size increases. This is not a good sign. In order to maintain the

good mobility in the urban areas, balanced modal splits should be encouraged. For this, appropriate transport systems have to be implemented.

One of the solutions is implementation of sustainable public transport systems in the urban areas which encourages commuters to use the systems for their travel. The Govt. of India launched Smart Cities Mission recently and proposes 100 Smart Cities with a mention of efficient urban mobility and public transport and sustainable environment. However, there is no mention of any guidelines considering different types of transportation systems.

### *3.5.2. Concept of Sustainable Urban Transport*

Sustainable transport systems would consider the parameters in a holistic way that includes efforts to mitigate negative effects on every part of the transportation system which are generally ignored in traditional transportation system planning. Sustainable transportation system must consider the interconnected issues, namely, social, economic and environmental.

#### *Steps Needed for Sustainable Public Transport Systems*

In order to achieve the sustainability in the public transport systems the following major steps should be considered (SUSTRANS, 2017)[11] :

- Quality Enhancement of Public Transport System: Identifying and improving certain parameters of public transport which can enhance quality of public transport and influence the private vehicle commuters to shift to public transport
- Feeder Transport System for major mode of Public Transport Systems: The last mile connectivity has to be implemented adequately to increase the share of public transport. This should consider accessibility aspects of feeder modes with appropriate infrastructure
- Parking Facilities at major Public Transport Terminals: To attract more private vehicle users towards public transport modes, appropriate parking facilities need to be provided at the public transport terminals
- Intelligent Transport Systems in Public Transport: The Information Systems in public transport would attract the private vehicle users and increase the ridership also. However, it is very important to decide which ITS technology is more appropriate in terms of overall effectiveness and practical feasibility for different objectives of transportation
- Sustainable integration of different public transportation system: Public transportation systems should not operate in isolation, but in coordination with other modes of transport (private modes as well as other public transport modes). The seamless accessibility across all the public transportation modes should be aimed in order to attract more and more private transport users
- Policy Level Sustainable Strategies to restrict / control usage of private vehicles: Some kind of incentives to use public transport and at the same time restriction on using the private transport. However, without implementing a good public transport system, it is not advisable to restrict the private modes
- Evaluation of Sustainable Transportation System (environment, social, safety and economy): A continuous evaluation system in terms of sustainability should be there in order to quantify benefits from the implemented systems and keep on modifying the policies and parameters to see the effectiveness in terms of sustainability as a whole

[11] *SUSTRANS (2017).Development and Application of Technologies for Sustainable Transportation SUSTRANS, Final Report, CSIR-Central Road Research Institute (CRRI), New Delhi, 2017.*

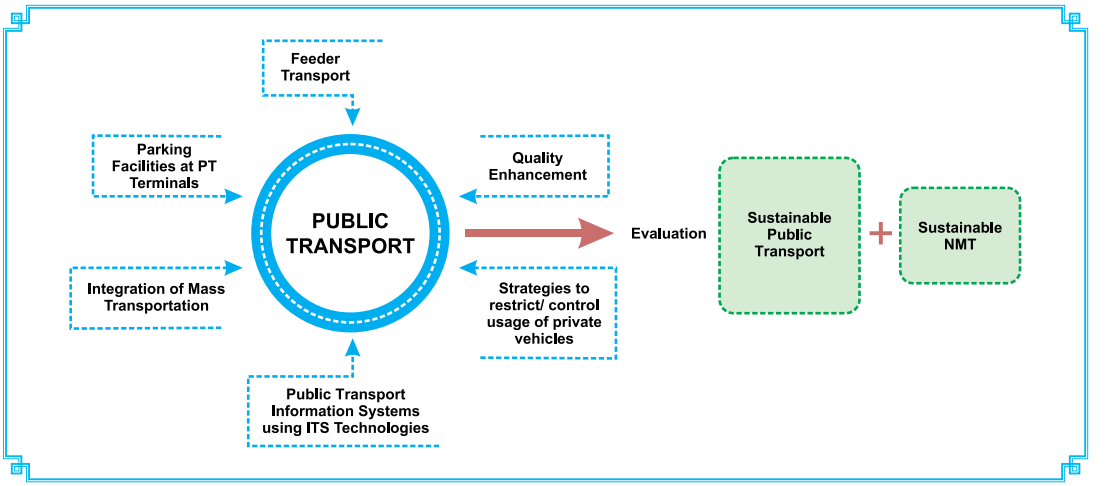



**Figure 3.31: Proposed Methodology for Achieving Sustainable Transportation System**
*(Source: SUSTRANS, 2017)*

By considering the above steps, the sustainable public transportation systems can be appropriately implemented by the authoritys/ transport corporations, policy makers etc. The schematic representation of above parameters that are to be considered in achieving sustainability is shown in Figure 3.31.

## 3.6. Intelligent Transport Systems (ITS)

### *3.6.1. Background and Concept*

As mentioned elsewhere too, Indian cities have a tremendous problem of traffic congestion, unpredictable delays due to traffic snarls, consequent increased atmospheric pollution, related road rage problems, enormous waste of man-hours due to the delays, etc. The basic problems behind this scenario arise from: limited land available for good roads, rapidly increasing population, steeply rising vehicle ownerships (4 wheelers and 2 wheelers), increasing shift away from public transport systems, inappropriate mix of road users (powered vehicles, bicycles, carts, cattle, pedestrians, poorly parked vehicles, encroachments, hawkers), culture issues arising from basic indiscipline, etc.

Some of the other issues are: lack of real time data on traffic congestions in various locations; traffic congestion due to excessive usage of key corridors by multi-velocity users; grid-locks at intersections due to indisciplined moves of vehicles and accidents; inefficient operations of signals; lack of knowledge of possible alternative routes to bypass traffic congestions; bus passengers not knowing the bus arrival times and travel times; difficulties in locating available parking areas; congestion and delays in Toll booths due to slow process in manual toll collection, etc. Another major problem is serious violations of traffic rules and difficulties of identifying traffic violators in congested junctions and urban roads. Freight movements within urban area is also critical, and ITS for efficiency of freight movement may be considered for better urban transport environment.

#### *Some possible solutions*

The above issues cannot be solved easily due

to limitations of land (unless multi-tier roads are built), demand side management limitations often due to vested interests, increasing middle class population yearning to own vehicles, enormity of problems for mass education for disciplined usage of public assets, etc.

Consequently, two possible solutions are: popularising public transport by making it attractive and use of Intelligent Transport System (ITS) to improve traffic problems as much as possible.

***Expectations***

- Free flow of traffic – time & cost savings, savings in man-hours, reduction of pollution (reduction of carbon footprint)
- Automated Traffic coordination and multi-modal integration
- Real time information on Traffic and guidelines to locate better traffic corridors
- Real-time Information for Passengers in public transport systems
- ITS can address most of these issues if properly implemented

### *3.6.2. ITS Tools and Techniques*

***Some Important ITS Concepts:***

ITS has many facets and modes. It can be implemented in modules in various areas or in a holistic manner in new urban developments or Smart Cities.

The following are some of the major concepts for ITS implementation:

- Overall Systems - Some of the overall systems which are possible in the introduction of ITS
- Electronic Toll Collection
- Bus control system – Buses with GPS; Automatic Passenger Counter system, Automatic Vehicle Locating (GPS), Vehicle asset management system; Route information system
- BRT control system - Signal priority, Vehicle tracking, Automatic fare Collection; Route Information System
- Remotely managed Traffic signal control system
- Parking Space identification and Facilitation system
- Real time Incident warning system
- Traffic Control System - Advanced integrated multi-modal regulation system
- Traffic violation detection and punishment system; Interceptor system
- Bicycle hire system for Metro stations
- Advance Traveller Information System (ATIS)
- Automated Variable Message Display Systems
- Automatic Traffic counter-cum-classifier system
- Vehicle actuated signals
- Multi-modal transportation System (Ex. Google Maps Routing systems)
- Commercial Vehicle Operation (CVO) for freight movement

***Technologies:***

ITS is an advanced technology and is a collection of multi-disciplinary systems, which are in various stages of evolution. For instance, it covers embedded systems, GPS, GPRS and GIS technologies, GSM and mobile computing technologies, Signal Processing, image processing, real time and cloud-based computing, instrumentation and sensor technologies, wired and wireless networking, machine learning, statistics, transportation engineering, etc., Hence, ITS is a conglomerate technology and requires advanced research institutions to be involved in its implementation.

The following are some of the technologies which can be used for the overall ITS system:

- Vehicle identifying, classifying and tracking systems; speed of travel estimation by tracking vehicles
- Remotely controlled CCTV cameras; Automatic Number Plate Recognition Systems (ANPRS)
- RFID based system for electronic payment of Toll
- Integrated fare collection system across Bus, Metro, MRTS/ Suburban rail; possibly toll payment also
- Automatic fare collection in buses with smart cards
- Traffic violation - Red light jumping detection: radar/ microwave/ laser detection and video/ still cameras & number plate recognition system; automated citations & Challans; Interceptors
- Telecommunication systems, vehicle-vehicle & Vehicle-Ground communications;
- LIDAR (Light Detection and Ranging) units with image capturing technologies

### 3.6.3. Policy Interventions Required

#### *Complexities of ITS Systems:*

ITS being an advanced technology comprising a host of hardware and software and requiring extensive deployment even for moderately large cities, is expensive and intricate for usage. Apart from political and bureaucratic backing it needs a carefully developed implementation strategy. The exact systems to be deployed, and the extents of usage will have to be determined after a thorough analysis of a city's problems, logistics and background. Extensive investigations should be made to identify the specific problems for the city and well-qualified research institutions should be involved for mapping out the deployment. Thorough training should be given to the staff involved and the involvement of experienced Project Management Consultants would be highly beneficial. Once set up, careful monitoring and fine adjustments will be necessary continuously. Regular monitoring at high levels would also be necessary. Otherwise, the system will fall into disuse, as for instance, well connected variable display systems being used only for broadcasting traffic safety slogans. Apart from the basic implementation of ITS, some of the useful peripheral actions which would facilitate the ITS systems in the long run are as below.

#### *Action Required by Various Authorities in an Integrated Manner:*

- Switch-over to standardised "smart" number plate system all over the country
- National database on vehicle registration data
- Active encouragement of RFID system for ETCS (Electronic Toll Collection System) payment of Tolls and more lanes in Toll booths for ETCS
- National database on Driving License data
- Setting up Integrated Traffic Control Centres in Cities
- Expert Traffic & Transportation Systems instead of Traffic Police operated systems
- Automated & Integrated Fare collection systems
- Traffic violation citation systems based on Automated violation detections
- Public Education Campaigns to utilise the ITS systems effectively

#### *Organisations Involved:*

Since most transportation issues come within the control of the States and traffic control within cities comes under local Traffic Police controls, coordination at national level may cause some problems and may require key legislation-based interventions. This would, however, be greatly beneficial as overall coordination and crime detection would also get greatly simplified.

Also, a shift of Traffic and Transportation management is required in as much as traffiic police is strongly supported by qualified Traffic Management experts who would handle the sophisticated ITS systems. This may require the formation of a centralised, nation-wide cadre of T&T experts.

The maintenance and operations of the ITS centres will also require a separate cadre of technicians and engineers.

***Impediments to Implementation of ITS:***

Some of the impediments to ITS Implementation are: High costs, lack of awareness, apathy in decision-making levels, wrong copying of western ITS practices which are totally unfit for the chaotic Indian conditions; Improper usage of the sophisticated hardware systems of ITS, lack of sustained applications leading to abandonment of good practices over time, etc. The experience in many Indian cities with some of the facets of ITS in the recent past attest to the above and calls for well thought out and determined implementation approaches.

Some specific actions are required to meet the challenges of ITS in India include (IRC:SP:110-2017 ):

- Availability of definite guidelines, standards and specifications in physical integration
- Integration of the ITS applications and development of standards/ specifications of equipments
- Cost management of ITS safety systems
- Setting up a city wide ITS implementation with fully functional traffic management centers
- National level data centers and maintenance of archived data
- Online or offline data modelling methods to handle huge data
- Development of ITS architecture at city, regional and national level along formulation of ITS policies and programs

### *3.6.4. Methodology of Implementation*

Quite a few ITS projects have been implemented in India mainly in Metros andother big cities like Delhi, Ahmedabad, Bengaluru, Chennai, Pune, etc. These various projects are of individual nature, and focus limited functions of the ITS, like traffic signal management, organised parking management, public transportation management and highway Toll collection centres to name a few. Most of these projects are pilot projects and are in primary operating stages for future large-scale implementation. The experience gained in the following examples of existing ITS practices in India should be used to guide further implementations (Rawal and Devadas, 2015):

***Advanced Traffic Management System:***

Chennai: Advanced Traffic Management System which comprises of putting up a complete monitoring system using surveillance cameras for traffic rules violators, especially at junctions, named as Traffic Regulatory Management System (TRMS) has been initiated in Chennai. Special purpose cameras having latest technology and high resolution image capturing capacities like Automatic Number Plate Reader-cameras, Pan Tilt Zoom cameras, and CCTV cameras have been installed at various locations in the city, for additional help at various junctions. Automatic Traffic Control system, along with TRMS helps to supervise and adjust the traffic flows without physical interference in deciding and changing the duration of signal waiting time, by the computerized analysis of next three signalized intersections and their synchronization. Apart from these systems, FM radio is also one of the significant sources of transmitting crucial information about traffic jams, road blockages due to extreme weather, etc. in Chennai.

Mumbai: An Area Traffic Control Project that

deals with management of traffic flows at major junctions has been implemented in Mumbai. Technological help is also taken from latest gadgets like accelerometer guns, smart cameras for vehicle number detection, radar sensor, etc.

Bengaluru and Hyderabad. A pilot project has been introduced where real-time traffic scenario of major intersection and its secondary connector roads can be obtained through internet in Bengaluru and Hyderabad. The real-time images are available 24x7 on this internet-based portal for these major intersections and these images are updated at every 15 second interval. In addition to internet advisory information system, SMS based system is also available to the road users and motorists to get the updates for traffic jams and restricted accesses due to ongoing construction and maintenance activities. This facility has been made available to the public for free, but prior registration has to be done to avail of these updates. The subscribers get these updates twice a day, i.e., in morning and evening peak hours.

New Delhi: In the year 2009 a pilot project known as 'The Traffic People' was launched to provide real time traffic conditions and updates of in-and-around New Delhi (including NCR region). Basically, with a web-based platform, this project was initiated for providing morning and evening peak hour traffic condition of selected locations. The idea was also to initiate SMS service with monthly subscription charges but this service failed to function due to weak response from the people and unavailability of the data.

### *Advanced Traveller Information System:*

Karnataka State Road Transport Corporation (KSRTC) Vehicle Tracking & Monitoring System (VTMS) project is planned to offer benefits to provide on time information to the stakeholders that include amongst others - KSRTC operating staff, Control Center Staff, Bus Stand Staff, Commuters. The system is expected to provide quality real time information on arrival and departure status, handling of incidents and accidents, increase safety of commuters and staff, reduce operational costs, improve traffic efficiency etc. The Global Positioning System (GPS) unit has to be mounted on board the bus and the assembly has to be designed in a way that integrates with the dashboard of the bus. The bidder has to provide a design which should be theft proof and cannot be in normal circumstances removed from the bus unless standard technique specified by the bidder is applied. Live tracking, tracking data, related reports etc. should be available on the server space provided by the bidder which should be secure and should be exclusively used by KSRTC. It should show fuel position on live tracking as well as back tracking. Fuel report should show actual fuel consumed / added so as to identify fuel loss/ pilferage. Location data of vehicles should be sent to the bus stands on real time basis which should be displayed on the display boards at the bus stands along with approximate time of arrival calculated on the basis of average speed of the vehicle. In this direction, one application has been implemented in Advanced Public Transport System (APTS) in Bengaluru, Chennai, Indore etc. to monitor vehicle routing and frequency so that passengers do not have to wait long hours for a bus. Especially in the city of Mysuru, the public transport information system using intelligent transportation system which has been implemented received lot of success. The details of the Mysore ITS (MITRA) are given in Chapter 4.

### *Other ITS:*

Several Electronic Toll Collection pilot projects have been proposed for major national highways, for example Chandigarh-Parwanu NH-5 and Ahmedabad-Mumbai highway. ITS is widely used in Bus Rapid Transit Systems projects and metro projects. Major ITS techniques applied in these projects are signal priority, vehicle tracking, surveillance and automatic fare collection. BRTS projects in the cities like Pune, Delhi, Ahmedabad, Indore, Mumbai, Hyderabad, Bengaluru,Chennai,

Coimbatore, Jaipur, Madurai, Nagpur, Vijayawada, and Visakhapatnam and metro projects Delhi, Mumbai, Bengaluru, Chennai, Hyderabad, Kolkata, Kochi, Jaipur, Ahmedabad, Nagpur, Pune, Lucknow, etc. have wide range of ITS applications. Advanced Parking Management System (APMS) is also one of the initiatives that involves application of ITS. Electronic Parking Guidance and VMS Smart Cards are a few technological solutions to parking management adopted in India. In Delhi, APMS has been applied and is under implementation at few parking lots and multi-level carparking for example, parking lot at Palika Bazar and automated multi-level parking in Sarojini Nagar Market, which are under execution.

### *3.6.5. Indian Experience with ITS*

#### *Overview*

a. There have already been several attempts to implement some measure of ITS in the various Indian cities. They cannot be said to be quite successful so far given the large financial investments. Hence any further implementation should be taken up after studying the work done so far, analysing the plus/delta and hence formulating the action strategy.

b. There is a strong case for standardised implementation in the various Indian cities, as many of the problems are standard across locations. Considerable advantage can be gained by having replications of the same system in several cities, as procurement of hardware, software and consultancy & implementation services can take advantage of the effect of scale. Training concerned personnel can also be centralised. The experience gained in the various locales can be shared across for mutual benefits. This again augurs well for a centralized all-India T&T Service catering to expert ITS implementations.

c. Of the various ITS measures, some of them can be implemented on a stand-alone mode and some of them require an integrated approach. They are examined below. Again, the overall strategy should be first determined, and all subsequent steps should fit into the overall scheme like jig-saw puzzles; i.e. the various steps can be implemented progressively one by one but the overall game plan, duly integrating all the measures, should be developed in advance and monitored for integration and cross-supports. Otherwise there will be wasteful efforts and expenditure on infrastructure. For instance, there is no point in going in for CCTV comers at various junctions without having the integrating features subsequently for effective action based on the inputs from the cameras. Also, subsequent steps may involve additional modes of sensors which again should be well integrated with the cameras.

#### *Some Steps for Stand-Alone Implementation of Sub-Systems*

The following steps are suggested for Implementation in stand-alone mode for each of them:

- ETC (Electronic Toll Collection System) is probably the simplest stand-alone measure. Toll collection systems on National Highways as well as within cities can be modified to facilitate this. This will increase the throughput of vehicles within the existing infrastructure, encourage cashless transactions and facilitate smooth movement of traffic.
- Introduction of Automatic Bus control systems for public transportation systems – Buses with GPS; Automatic Passenger Counter system; Automatic Vehicle Locating(GPS); Route information system within the bus, in bus stands and on the Net; Vehicle-Base Communication system; Vehicle asset management system, etc. This is again an independent system and with improvement in efficiency will encourage

people to shift to public transport, improve throughput of commuters and help in efficient management of the asset base. Similarly, Bus Rapid Transport (BRT) Systems also can benefit well. Somehow the existing BRT systems in Indian cities have not taken off well and the problems faced with them should first be studied before embarking on new projects.

- Internet hotspots with captive traffic information dissemination systems at bus stations/ metro stations, etc. will facilitate the above. This internet provision should cater exclusively to public transportation usage to prevent misuse.
- Universal contactless Smart Cards for fare payment which would be valid across all public transportation systems in a city covering buses, BRT, metro, suburban railway, toll payment, etc. would be very useful and encourage the use of public transportation systems, and also cashless transactions.
- Integrated Information System or City Traffic App for multi-modal transport systems in a city. This will give real time information on how to get from point A to point B or Corridor information in a city in the most efficient manner using public transport systems, rather like the visual help one gets from Google Maps. This will again encourage use of public transportation. This can also be linked up with IPT Intermediate Public Transport, such as Call taxis (like Ola, Uber, self-drive hire cars, etc.) to provide intermediate connectivity. If backed up with real time traffic congestion data, this can be of great use to commuters. This can also give information on traffic congestion locations, availability of parking, pollution levels, etc.
- Integrated Parking Information System (IPIS). This will facilitate drivers to quickly locate nearby vacant parking slots and avoid their unnecessary circling around or illegal parking causing obstruction to traffic. This can also be linked up with the system given in 4.1 (the Section on Parking Systems) above. This would be based on a GIS system covering centralized (automated) parking structures, (semi-automated) road-side municipal parking lots and (automated) parking lots in public facilities such as airports/ railway stations/ bus stations, etc. The automated lots will have slot occupancy identification systems, variable information display panels giving real-time information on nearest vacant slot after determining the car's position. The semi-automated systems will involve the parking attendant carrying a hand-held (POS) machine which will issue tickets for identified slots and clearing them after the car vacates the slot. Wide Area Network connection of all the parking system with centralized coordination will facilitate the IPIS. This again can be implemented independently
- Building up automated centralised transportation database. This will cover all data regarding all registered vehicles and driving licenses. This will facilitate tracking vehicles past various intersections using number plate recognition technology and catch errant drivers and challaning them electronically. Implementing uniform standardised "smart" number plates which can embed RFID (passive, Radio Frequency Identification Device) units would be a great help to track any vehicle anywhere instantaneously, both for aiding as well as for catching errant drivers. This will also progressively do away with the need for deploying other sensors to detect vehicles. The driving licenses can also be "smart" cards with passive identification device embedded. Insisting on automated driver testing systems using on-line examinations and driving tests using 3D simulations would be a spin-off benefit from these smart licenses.
- Cameras at various intersections and key locations. These can be of fixed orientation or the tilt-pan-zoom type. They can be linked up with radar-type systems for speed checks and Number Plate Recognition Systems for

traffic detection and detection of violations. However, it is highly recommended that the cameras should be designed to be part of a (subsequent) overall integrated system of sensors, feedbacks and controls.

### *Integrated Systems – Automated Traffic Control Systems, Control Rooms and Real-Time Management*

The following systems will involve a network of hardware and software systems, all dovetailing into an overall Automated Traffic Control System (ATCS) for the city. The ATCS can be a centralised one for the entire city or can be in hub-and-spokes concepts with independent satellite systems all connected to a centralised hub. The main components of this system would be:

- Sensors/ input devices – CCTV cameras, passive data collection from mobiles in cars, data from RFID devices and Bluetooth devices in vehicles, ANPRS (Automatic Number Plate Recognition System); vehicle sensors/ mobile sensors at all junctions to assess traffic volumes and initiate automated regulation and signal cycle time variation. In a more advanced state the lighting pole and electric poles on the road sides can also be mobilised, with locations of appropriate sensors in them, as data capturing devices. Equipping vehicles with RFID-embedded licence plates will facilitate this technology
- Network for transmitting the information collected by the sensors instantaneously
- Filters to take out the "noise" from the sensors, validate them for correlation and feed them to the central processing unit
- Servers or cloud based central processing units which crunch the huge amount of data and give out processed real time information
- Control Rooms: Control rooms for monitoring the processed information and taking action in an automatic manner or with manual intervention; Central and Distributed Traffic Control Centres (TV Wall with Camera-relayed pictures, Real time traffic count data, Real time Bus & Metro locations, Signal control systems, Incident Detections & Follow-up, Variable Message Display systems, information databases and Geographic Information Systems (GIS); Communication centres, Cloud-based servers, etc.); Predictive Traffic Management
- Inter-connected traffic signals which can be remotely operated from control rooms
- Variable display information panels giving out real-time information automatically or with manual inputs
- Coordinated Interceptor teams which can provide help at "incident" spots or apprehend traffic violators
- Training operators, Drivers, Public; Public Information Campaigns

### *Multi-Modal System Facilitation with ITS*

ITS can facilitate Multi-Modal Transportation in following ways: providing overall information about availability of the various modes of transportation across the city, identifying optimum/ possible routes from Point A to Point B in the City using the various available modes of traffic at a given point of time, facilitating the use of a single ticket system across the various modes of traffic, locating nearest available parking spaces when switching over from one mode of transportation to another, optimising the schedules for the various modes at various key locations in the City at various specific timings to facilitate quick connections, as for instance, facilitating quick connections in morning or evening peak hours at important change-over stations, etc. Apps can also be developed to provide such information for specific city ecosystems.

### *Organisational Aspects*

As already mentioned an all-India cadre of T&T specialists, particularly for ITS operations, would

be highly desirable. The organisation should provide for various types of specialists of various levels of expertise and experience, their training, career planning, etc. Jurisdictional rules, powers to be vested, precedence levels vis-à-vis other cadres operating in T&T areas, etc.

#### *Resources*

In view of the vast resources required in terms of human levels and hardware and software provisions, migrations to be made from existing conventional systems into ITS, training of personnel, expenses to be incurred in mass education campaigns, etc., careful planning has to be made while planning ITS-based systems. While funding from Centre, State and City levels would be required, aid from multi-lateral agencies may also need to be explored. The returns from such massive investments may not be tangible or quantifiable and may be of social, quasi-economic (such as savings in man-hours of working populations due to smoothened traffic patterns), environmental and ecological benefits only.

#### *Time Frame for Implementation*

The actual time required for implementing ITS systems would depend upon the extent and type of implementation and cannot be quantified easily a priori. Considerable time would be required in the beginning for planning, thereafter for identifying specific systems, later for procurement of relevant hardware and software, recruitment and training of expert personnel, public education campaigns, installation of the systems on the ground, testing and commissioning finally leading to operations phase. The intervening time would certainly be in the range of a few years, possibly 2 to 5 years depending on the complexity levels involved and the experience gained with progressive implementations.

### *3.6.6. Spin-off Benefits*

- Buses: run-time monitoring, interventions in emergencies, route diversions in cases of traffic snarls, passenger information system, optimisation of fuel consumption with better driving patterns; automated demand-based service provision
- Passengers: real-time bus arrival information system, estimated run time to reach destinations, automated fare collection; more buses on heavy demand routes; possible diversion of nearby routes to collect more passengers; also, data on the net
- Public: Optimised public transportation operations, cashless transactions, traffic congestion data availability, real time monitoring of pollution levels, identification of optimum route from point A to point B across multi-modal systems
- Drivers: traffic congestion warnings, parking availability information
- Traffic monitoring:
  - Possibility of creating “green” corridors in times of emergencies
  - Intermediate Transport systems being facilitated
  - Multimodal transportation System App possible
  - Demand management, capacity planning, traffic corridor planning, multi-modal integration, all possible for future developments
  - Detection of Vehicles in Congestion Levy Zones and automated debit systems using RFID/ NPRS

## 3.7. Road Safety

### *3.7.1. Background and Status*

Road safety has become a critical issue in view of the large number of fatalities arising out of road accidents. Fatalities arising from road accidents have become the second or third largest killer in the country. With the growing population of human beings as well as vehicles, this situation is only getting worse. So much so that every

hour some nine deaths are taking place due to road accidents. 55% of the people involved are pedestrians and 35% of this are children. This alarming situation calls for immediate attention and remediation, as the trend is only increasing at a fast rate in view of the limitation on expansion of road network but increasing number of vehicles which are coming out with increasing capacity for acceleration and speed. Road Safety campaigns based on appropriate measures covering the entire spectrum of causes and behavioural patterns are required urgently.

The road safety situation is governed by many factors: drivers and their driving skills and abilities; Pedestrians and other road users; state of the road ecosystem in terms of space as well as organisation of space, geometrics, quality, lighting, signaling, etc.; state of the vehicles using the roads, etc. Any road safety improvement campaign must address all these factors.

Any road safety campaign must be based on a good understanding of the dynamics of accidents, the behavioural patterns of the people involved, the limitations of the infrastructure, etc. and base the safety education campaign on such learning. Fortunately in the recent past there is a growing interest in studying behavioural counter-measures, leveraging measures centered on changing human behaviour through education and publicity. The measures have to be based on a proper appreciation of how and why people act as they do on the roads. 'Behaviour' refers to what people do, not what they are able to do, and thus includes factors such as the perception and acceptance of risk, cultural and peer-group pressures, and so on.

Some of the problems causing road safety issues are as below:

- Bad Driving: Aggressive driving, rash driving, driving under the influence of liquor and drugs, incompetent driving, driving by youngsters below legal age or unlicensed drivers, lack of knowledge of traffic rules and driving ethics, over speeding, driving without lights in night time, wrong parking
- Violation of traffic rules: Driving on the wrong side of the road particularly where high medians prevent cutting across the road, driving the wrong way in one-way streets, not wearing helmets or seat belts, overloading of vehicles, jumping signals, jay walking, crossing the road at locations other than pedestrian crossings
- Defective Vehicles: Vehicles which are not roadworthy, illegal vehicles such as motorised hand carts
- Poor roads: Narrow roads, roads with poor surfacing, pot holes, water ponding due to poor drainage, insufficient lighting in nights, bad geometrics
- Insufficient enforcement: Inadequate number of traffic policemen, incompetency of various forms in policing, lack of traffic signals at key intersections

All the above issues must be addressed properly while devising road safety campaigns. Some of the road safety measures and campaigns are discussed below.

### *3.7.2. Public Education and Awareness*

#### *Through School Education:*

Indiscipline, disregard for traffic rules, lack of knowledge of traffic rules, care and respect for other users of the road, etc can be addressed to a major extent through educating the children in the formative years, so much so that they in turn start correcting the elders in their families. Apart from making traffic education as part of the curriculum, children should be given practical training in enforcing traffic rules by assisting traffic police.

#### *Through Media Campaigns:*

In present day context the media have come out to be a powerful factor for influencing the

perceptions, outlook and behaviour of people. Research indicates that people are most likely to change their behaviour following mass education that has the following characteristics:

- includes specific detailed recommendations of the behaviour in question and how to modify it;
- perceived as coming from a highly credible source;
- balances the pros and cons of an argument rather than being purely one sided;
- draws the conclusions clearly for the audience;
- is combined with the enforcement of effective laws.

Road safety mass media campaigns can achieve, and have achieved, the following:

- an increased awareness of a problem or a behaviour;
- a raise in the level of information about a topic or issue;
- help in the formation of beliefs, especially where beliefs are not held formally;
- the establishment of a topic as more salient;
- sensitisation of the audience to other forms of communication.

Apart from addressing the driving population, pedestrians should also be addressed to prevent jay walking, crossing at random locations, using mobile phones while walking on the roads, etc.

Advertisements in TV and cinemas using high profile people, short videos and skits, street plays, etc. have a great effect on moulding the perceptions and behaviours. The huge amounts of money sent on TV advertisements gives a clear idea of the perceived high influence of media campaigns.

***Through NGOs:***

Many NGOs are engaged in promoting road safety through various types of campaigns. Well-made promotional materials can be made available to them as well as adequate funds from governmental sources and public donations. Regular celebration of safety Week and Safety Month should be encouraged.

***Through Driving Schools:***

It is well known that those drivers who choose a wide margin of safety can cope more easily with the errors of others, including the children, the elderly, the drunk and the incompetent. Proponents of driver education, particularly of children while still at school, hold that instruction is crucial. However, the present-day driving schools are manned by incompetent people who are barely able to teach only the fundamentals of managing the various controls of a motor vehicle. They do not teach the finer aspects of defensive driving, awareness of various types of traffic rules, respect and care for the other users of the road, emergency medical care, etc. “Train the Trainers” type of programmes are required to be developed by competent agencies and used to train the driving school instructors through special schools. Such instructors should be licensed only when they pass such courses.

***Through Hoardings:***

Hoardings are ubiquitous in many urban locations and well-made hoardings with good traffic safety messages will help. Such messages should be attractively pictorial for rapid absorption by the travelling public and not verbose in content.

### *3.7.3. Measures for Road Safety*

***Driving Tests and Required Learning:***

The present-day driving tests are very cursory and rather quickly performed. These are not comprehensive like in developed countries, where an online-based objective-oriented multiple-choice type written test based on standard compiled

material, covering driving habits, road signs, road ethics, emergency care, etc.is given. Since the level of literacy in our country is not that high, the questions can be vocalised through appropriate software and answers can be chosen by punching on pictorial multiple-choice type of answers. Using standard algorithms, questions from standard data banks can be mixed up for each respondent to minimise chances of copying and software-based answer evaluation systems can pass or fail a person very quickly. A minimum level of literacy should be mandated for granting licenses.

Going further, the driving skills can also be tested by simulations based on animated games-like situations to see how a person responds to standard driving situations. License renewals every 5 years should always be based on repeated tests. The authentication for writing the test can be done through Aadhar card to ensure that no person gets a license without being tested and to avoid multiple licenses for the same person.

### *State of the Vehicles Using the Road:*

Vehicle road worthiness certification should be made mandatory every 3 to 5 years. All vehicles should be thoroughly checked and certified. For all new vehicles the following may be made mandatory: High-mounted rear brake lights, day-time headlights, side view mirrors on both sides, seat belts, air bags, ABS, etc. Going one step further, for starting a car a valid smart-card based license should be made necessary through electronic means.

### *State of the Road Ecosystem:*

Many deaths have been reported in cities due to two-wheelers hitting illegal speed breakers or raised manhole covers or medians without any warning markers, etc. Roads should be maintained by the respective authorities in good condition. Urban roads should be checked for condition every three months and other roads every six months by the respective authorities and required maintenance done. Specialised consultants well familiar with IRC system of Road Geometrics should certify all new roads to eliminate black spots and inclement geometrics. Minimum lux levels should be specified and ensured for road lighting in urban areas. Regular checks should be carried out on signalling systems to ensure proper functioning and other intersections checked periodically to test whether they need signalling. Adequate provisions should be made for pedestrian crossings (signal-based), underpasses and overbridges for pedestrians. Special cycle tracks are another necessity.

### *Through Rigorous Enforcement:*

Good policies and systems are ineffective unless enforced rigorously. Traffic police should be freed from planning duties (which are proposed to be carried out by a special cadre of Traffic and Transportation specialists) and entrusted with only enforcement. At minimum the following should be enforced: helmets for rider and pillion rider for two wheelers, not more than two riders on two wheelers, wearing seat belts for front seats, functioning brake lights, no overloading in size or weight, pedestrian crossings only in designated zones, parking only in specified locations, prohibit use of mobile phones on the road, preventing unlicensed vehicles on the road, avoiding signal-jumping, and so on. Driving licenses should be made smart card-based so that all violations can be recorded on the cards and punishment matches repeated violations. At key intersections CCTV cameras should be installed, backed up by a number plate recognition system to detect offenders and send automated traffic challans.

### *Accident Care:*

Special measures should be taken to provide emergency medical care for accident victims within and outside urban locations. Enough ambulances, cranes, etc should be made available. Enforcement personnel should be

trained in emergency medical aid and trauma care. Names and telephone numbers of public emergency care hospitals in the vicinity should be displayed at various locations.

***Research into Road Safety:***

Since many complex issues are involved in understanding and predicting road usage behavioural patterns, good research into road safety should be encouraged and properly funded through governmental and donor-based financing. The performance and behaviour of motorcyclists have also long been a matter of special concern, and research should also cover new training and test methods. Road safety statistics are very important to measure the efficacy of the steps being taken from time to time as well as for public information to indicate the seriousness of the situation. The RTOs and other enforcement agencies should be made responsible for transmitting data to a centralised database as and when any situation occurs. Road accident statistics should be prominently displayed at many places to drive home the seriousness of the issue to the public at large.

***Policy Measures:***

Many of the factors mentioned above should be covered by policies and legislation enacted specifically. Such policies and legislation should be rigorously enforced. Road safety education should build support for laws and their enforcement, explaining what the laws mean, and to maintain a high visibility for the laws so that a high perceived risk of apprehension is maintained.

### *3.7.4. Expected Outcomes*

Evaluation of measures is an essential step towards making education more effective, and outcomes may validly embrace goals that are wider than accident prevention alone. Statistics of road usage and safety data should be collected by the concerned agencies regularly to check the efficacy of the various measures implemented on local, regional and national base.

## 3.8. Human Resources and Skill Development

### *3.8.1. Need for Professional Engineers*

The Prime Minister's initiatives have resulted in the launching of several schemes for a safe and sustainable environment like 'Smart and Amrut cities', 'Make in India', 'Housing for all by 2022', 'Swach Bharat Abhiyan' and the target of constructing National Highways at the rate of 42 km/day and supplementing them with inland waterways. We can add to this the long list of cities where metro project constructions are in progress or are in an advance planning stage, as well as high speed train corridors and development of ports. The inevitable conclusion is that never before in India have such ambitious investments in construction and infrastructure been envisioned. Such projects require skills of the highest order from Civil Engineers and those from other engineering disciplines. These schemes need big ideas, ideas that will make a difference, ideas that will open doors and result in break-throughs. We need an organised work force which can visualise a better India beyond the status-quo, which will need new levels of technical excellence. To exploit the inherent inventiveness of engineers for these schemes we require a cohesive and cogent planning at a national level by the Government and an active commitment to give the profession of engineering a statutory stamp.

India has a high vulnerability profile from the point of view of natural disasters like earthquake, cyclones and floods. To complete the profile, we must add man-made disasters, such as pollution, unsafe buildings, haphazard planning and over-crowding in cities and road accidents (400 fatalities per day in 2015). These calamities threaten India's economy, the safety and security

of its population as well as its sustainable development. Engineers, by education, training and experience are well-equipped to make a significant contribution to ameliorate these hazards.

"PROFESSIONAL ENGINEER" is an accreditation for Competence + Responsibility

In cases where public safety, property or welfare is concerned, it should be essential that all engineers working in a responsible capacity on such projects be licensed or registered as is the norm in large number of countries.

### 3.8.2. Present Scenario

#### In India

The engineering population in India has reached an estimated 7.5 million and is increasing at the rate of 1.5 million per annum. Even if 5 - 10% of these are connected with infrastructure, the numbers are huge. At present, the engineering profession is both unorganised and unregulated. While the Government brought Acts of Parliament after Independence for the regulation of some other much smaller professions, the Engineers seem to have been inadvertently overlooked.

A Committee under the chairmanship of S. G. Barve was set up by the Planning Commission in February 1966 to study the problems relating to technical consultancy services. The Committee's Report submitted in 1970, recommended that "in order to develop the profession on healthy lines and to avoid undesirable elements/ practices there should be an All India Institution/ Association on the lines of the Indian Institute of Chartered Accountants to lay down proper standards of education, experience, capability, capacity etc." The Chartered Accountants Act had already come into being in 1949. The Report further recommended that "legislation could be undertaken to make it (the Institution) a legal entity parallel to the Institute of Chartered Accountants".

It is a sad commentary that even after half a century this important piece of legislation has not seen the light of day. Incidentally, the total numbers of Chartered Accountants, mentioned by the Barve Report are but a small fraction of numbers of Engineers, i.e., 240,000 out of which only about 50% are in practice.

#### Other Countries, Other Professions:

In most countries, e.g., Australia, Canada, Japan, Malaysia, New Zealand, Pakistan, Sri Lanka, South Africa, Singapore, Tanzania, USA, etc. professions like Engineering are invariably governed by an Act of the Government. In India too, some professions, like that of Chartered Accountants, Doctors, Architects and Lawyers are indeed governed by Acts of Parliament.

### 3.8.3. Engineers Bill

After the Kutch earthquake on 26th January 2001, the State of Gujarat felt the need of regulation of Engineers and as a consequence the Gujarat Professional Civil Engineers Act, 2006 came into being. The need of the hour is to have a similar enactment on a national scale, to ensure the safety and security of the general public as well as that of the physical assets of the nation.

A mechanism for accreditation by an act of parliament is essential to set proper engineering standards including those in the infrastructure sector.

The Institution of Engineers (India) is currently involved in the Certification of Professional Engineers. However, being of purely voluntary nature with somewhat demanding systems and procedures in line with international norms set up by IPEA (International Professional Engineers Agreement), very few engineers are coming forward to take exams and ensure participation in Continuous Professional Development programs.

# TYPICAL SUCCESS STORIES

**Life in Delhi Metro** With its vast network of over 350 km spread across Delhi-NCR, the Delhi Metro has truly become Lifeline of the region. Every day on an average around 6 million passenger trips are carried by one of the biggest urban infrastructure intervention in the country.

# 4. TYPICAL SUCCESS STORIES

## 4.1. Advanced Parking Management Systems (APMS)

### *4.1.1. Experiences of APMS Installed at Palika Bazaar, Connaught Place*

The APMS is a significant part of the Intelligent Transportation System (ITS) and it obtains information about available parking spaces, processes and presents it to drivers by means of VMS. APMS has been used in two ways: to guide drivers in congested areas to the nearest parking facility with empty parking spaces and to guide drivers within parking facilities to empty spaces. The APMS has been installed as Underground Automatic Parking System at Palika Bazaar, Connaught place in New Delhi to disseminate information on parking lot usage through Variable Message Signs (VMS). The typical view of installed APMS at Palika Bazaar Connaught Place is shown in Figure 4.1.

The salient features of APMS at Palika Bazaar are given below:

- Entry to Palika Parking is from Janpath & Baba Kharak Singh Marg.


**Figure 4.1: Typical Views of Installed APMS at Palika Bazaar Connaught Place**

- Parking Facility opens from 8 am to 10 pm.
- On an average, 2000 - 2200 vehicles were reported to be using this parking facility daily.
- At present, three parking levels, consisting of one ground level parking and two basement levels (i.e. Levels I and II) is provided to accommodate about 2000 vehicles (1300 Cars and 700 Two-wheelers) at any point of time.
- Parking Lot VMS installed in and around parking facility to guide drivers about overall status of parking lot.
- Parking level VMS installed near entry of each level to guide the driver about status of that particular level.

The benefits of installation of APMS at Palika Bazaar have been evaluated by comparing itwith the situation before installation of APMS, as given below:

- APMS has ensured 16 % increase in parking and 27 % increase in revenue
- Increase in usage due to the display through VMS
- Increase in revenue due to the fool proof control
- Economic viability analysis yields encouraging EIRR results

### *4.1.2. Capitol Point MLCP Connaught Place*

Capitol Point is India's biggest fully automated Multi-Level Car Parking (MLCP) system with 1408 parking spaces covering 81,312 sqft of premium office / retail space with ground and first floor implemented by DLF and NDMC. The Capitol Point enjoys prime location on Baba Kharak Singh Marg, Connaught Place, which is suitable for high end office / retail occupiers. It also has an added advantage of being next to Metro Airport Express Line.

The highlights are given below:

- CBD - The project is part of the Central Business Distt. of the Capital.
- Approach - The approach is easy and avoids traffic congestion
- Access - All GF shops have direct access from the road.
- Automated Parking - The project has 1408 slots.
- Other - AHUs, firefighting amenities, fire escapes, and the overall best quality of construction.

The Multi-Level Car Parking (MLCP) works on


**Figure 4.2: Some Views of Installed MCLP at Connaught Place, New Delhi**

a pallet based technology moving on conveyor beds; which comprises of jig-saw puzzle system. These pallets act in synchronisation with the car lifts installed at suitable locations in the project. The car lifts and pallets act in unison with the specifically developed software system. This software also works as customer interface i.e. receive the command for particular requirement of parking and retrieval; and in turn order the pallets/conveyors to act accordingly. This technology is new in India and has not been installed at such a scale. Typical views of installed MCLP at Connaught Place, New Delhi are shown in Figure 4.2.

dedicated to the car park for 824 vehicles. The 7 levels of car-park cover 1,54,030 sq. ft. of the built-up area.Typical views of installed MCLP at Sarojini Nagar, New Delhi are shown in Figure 4.3.

### *4.1.4. MLCP at Delhi High Court*

The city's first automated underground Multi-Level Car Parking has been implemented at the Delhi High Court which will ease the parking problems of lawyers, litigants and the staff. The parking facility has been built by Delhi Metro Rail Corporation (DMRC) at a cost of ₹ 182.71 crore. The parking can accommodate 1,467 cars at six different basement levels. The first basement

**Figure 4.3: Some Views of Installed MCLP at Sarojini Nagar, New Delhi**

### *4.1.3. South Square MLCP Sarojini Nagar*

As part of its infrastructure development initiatives, DLF, under the Public-Private-Partnership module with New Delhi Municipal Council (NDMC), has developed Automated Multi Level Car Parking facility at Sarojini Nagar called South Square. The project is being executed on a Build, Operate and Transfer basis. Spread on a total area of 40750 sq. ft. and a huge built-up area of 2,20,364 sq. ft., South Square has a total of 10 levels, including basement which is used as the Parking Bay. The Ground & 1st Floor would have a total of 105 commercial units, while the 2nd- 8th floors are is 'In and Out' level where car owners will have to leave their vehicles in one of the 20 car lifts available there. The car would be automatically taken to lower floors at basement level 1 to 5 by the system and parked at the available slot. The sixth basement is meant for SUVs. The sensor at the lift would identify the SUV and take it directly to sixth floor.

Apart from parking of 1,467 cars at various basement levels, an additional parking of 51 cars is available at I/O level for any emergency situation. The maximum parking or retrieval time for a car would be three minutes. This is situated on Shershah Suri Marg opposite the

High Court on a 9,864-square metre plot, the parking has an aesthetic view with modern landscaping. Provisions have also been made for amphitheatre, sitting arrangements for general public, a cafeteria, drivers` lounge and public convenience facilities at deck level. The parking has user-friendly signage and a pedestrian underpass connected with the High Court through a pedestrian way provided with escalator facility. The availability of parking lots would be displayed through digital signage at the entry point. Typical views of installed MCLP at Delhi High Court are shown in Figure 4.4.


**Figure 4.4: Some Views of Installed MCLP at Delhi High Court**

## 4.2. Advanced Public Transport Information System (APTIS)

### *4.2.1. General*

One application of an Advanced Public Transport System (APTS) has been implemented, as a GPS vehicle tracking system in public transport buses (Bengaluru, Chennai, Indore) to monitor vehicle routing and frequency so that passengers do not have to wait long hours for a bus. The objective is to provide Global Positioning System based passenger information system to help passengers utilize their waiting time at bus stops more efficiently as well as to reduce the uncertainty and associated frustrations. Display boards with high quality light emitting diode in wide view angle are provided at bus stops so that passengers can read the information. It displays the number and destination of the approaching bus, expected time of arrival and messages of public interest (Lelitha,et. al., 2010)[14].

### *4.2.2. Mysore ITS (MITRA)*

***Overview of MITRA[15] :***

- Real-time monitoring and tracking of buses and help reduce road congestion and other transport issues
- ITS solution provides dynamic Passenger Information System (PIS) based on Geographical Positioning System (GPS)
- ITS applies advanced display and communication technologies, Central Control Station (CCS) and intelligent display boards
- ITS improves passenger safety, fleet efficiency, services and traffic situation through transmission of real time information

*[14]Lelitha, V., Gitakrishnan, R. and Asha, A. (2010), Intelligent Transportation Systems, synthesis report on ITS including Issues and Challenges in India, IIT Madras.*
*[15]Mysore Intelligent Transport System (MITRA), Karnataka State Road Transport Corporation (KSRTC) http://mitra.ksrtc.in/MysoreMBus/index_e.jsp*


**Figure 4.5: Typical Description of Implemented Mysore ITS (MITRA)**

***Objectives:***

- Increase the Number of Commuters in KSRTC Mysuru
- Improve traffic safety
- Relieve traffic congestion
- Improve transportation efficiency
- Increase the energy efficiency
- Promote the development of related industries

***Benefits for Passengers:***

- Increase the accessibility of the system
- Increase the safety of users
- Display and announce current and next stop details inside the bus
- Display expected time of arrival (ETA) of next bus on the bus stop display boards
- Real time bus information through SMS and IVRS facility
- Reduction in waiting time and uncertainty and improve in overall bus service reliability

***Benefits for Bus Crew:***

- ITS helps in improving operational efficiency through proper scheduling and monitoring
- ITS enables two-way communication between bus driver and Central Control Station (CCS)
- ITS helps in improving crew driving habits
- Reduce the fuel consumption and emissions
- ITS can enable financial benefits due to increase in passenger loyalty and passenger shift from other modes of travel

The typical views of Mysore ITS is shown in Figure 4.5. The bus route and bus tracking system for a typical route is shown in Figure 4.6.

***Economic Analysis of APTIS of Mysuru City:***

Economic analysis is conducted to measure the economic viability for the commuter using the APTIS. SUSTRANS (2017) has carried out economic analysis from the calculated benefits and costs incurred using APTIS, considering certain parameters such as change in waiting time and journey time, which are converted into monetary terms by using the value of time concept. The personnel income is then further expressed into per min income. For economic analysis purpose the value obtained for increase in waiting time and journey time of user is considered to be a negative factor. From the SUSTRANS study it was found that on an average about ₹1.54 crores/month is saved for the APTIS users. Total population of the Mysuru city as

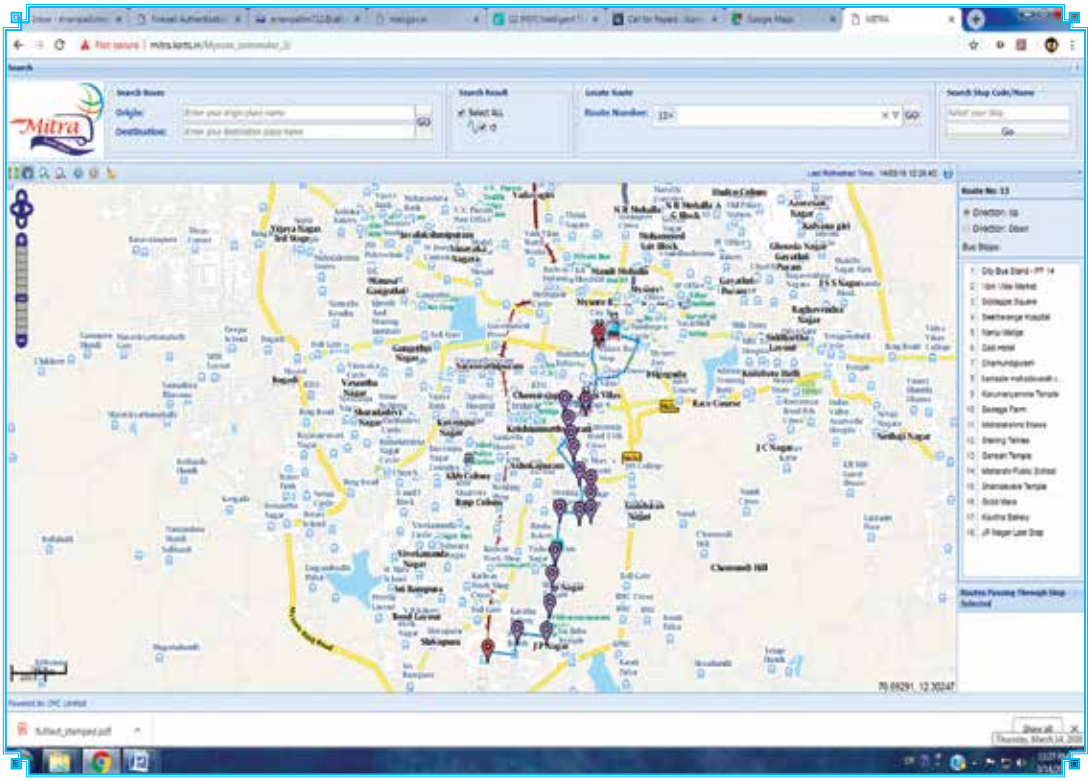



**Figure 4.6: Bus Route and Bus Tracking System for a Typical Route in Mysuru**

per Indian census is 9.95 lakh and as per the Karnataka state road transport corporation report it is estimated that about 5.7 lakh passenger trips are generated each day within urban limit, out of that 13% are using public shares. The study has also estimated that a total of 66% users are following the APTIS. From personnel income data the weighted average income is calculated and similarly the weighted average time saved using APTIS is also calculated. The estimated parameters for economic analysis are presented in Table 4.1. From the Table 4.1, it can be seen that by using APTIS about ₹ 18.55 crores / year is saved by the users. It can be inferred from the analysis that the passengers had benefited the most after APTIS system had been installed.

### *ITS Based Operations of KSRTC Buses in Mysuru City:*

KSRTC, Mysuru deployed Intelligent Transport System (ITS) for the city bus operations in order to achieve operational efficiency and attract increased ridership for higher modal share. The ITS ecosystem stabilized after many technology related teething troubles and was certified and formalized in September 2015 over a period of more than three years. Till April 2018 KSRTC could not take up suitably planned and extensive outreach programme activities, for enhancing the success level for the first ever implementation of the ITS enabled bus system anywhere in India.

| S. No. | Indicator | | Value |
|---|---|---|---|
| 1 | Total Population of Mysuru | | 99,5000 |
| 2 | Estimated passenger trip generated per day | | 5,70,000 |
| 3 | Trips by Public Transport (13% of value in (2)) | | 74,100 |
| 4 | No. of People Following APTIS (66% of value in (3)) | | 48,906 |
| 5 | Average time saved (min) | | 11 |
| 6 | Weighted income (₹) (considering | per month | 13,795 |
| 7 | 8 working hour per day) | per minute | 0.96 |
| 8 | Cost Saved (in ₹) | per trip per person | 10.54 |
| 9 | | per day | 5,15,364 |
| 10 | | per month | 1,54,60,917 |
| 11 | | per annum | 18,55,31,003 |

*Source: SUSTRANS, 20017*[16]

**Table 4.1: Economic Analysis of APTIS Implemented in Mysuru City**

KSRTC operated about 6120 trips in 2012 through 404 schedules from 3 depots on 154 routes every day in Mysuru serving a total number of 1312 bus stops in the city. The ITS project has been a turnkey project (funded by World Bank), which included supply of hardware, software integration, commissioning, system testing, training and three years of maintenance. The project had KSRTC as user champion in Project Implementation Unit, with IBI Group as the Project Management Agency (PMA) and CMC Ltd. (later owned by TCS) as ITS vendor. CMC has dealt with design, development, supply, installation testing, commissioning, training, operation and management of the ITS component, while PMA had overseen the integration, scope, time, cost, quality human resource, communications, risks and procurement to ensure professional management of the project.

The following were the original components of the ITS project, which have been enhanced and modified in some cases later during actual implementation:

1. Automatic Vehicle Location Information System (AVL-IS), including the Global Positioning System (GPS) antennas on all buses.
2. Passenger Information System (PIS)
   (a) Information display services: in-vehicle (500 units), including display board and annunciators
   (b) Information display services: bus stops (105 stops)
   (c) Information display services: stations (6 stations) & 45 platforms
   (d) SMS bus arrival information requests
   (e) Interactive Voice Recognition System (IVRS) to obtain bus arrival information
   (f) Web application for customer access
3. Driver-support information system (through Vehicle Monitoring Units (VMU), including emergency call button and two-way voice communication. The VMU unit is equipped with

[16]*SUSTRANS (2017). Development and Application of Technologies for Sustainable Transportation SUSTRANS, Final Report, CSIR-Central Road Research Institute (CRRI), New Delhi, 2017.*

a SIM card for data and voice communication capability.

4. Automated voice announcement system on buses
5. Central Control Station (CCS) for operational management
6. Vehicle identification and tracking through web application (at CCS)

The Vehicle Monitoring Unit (VMU) is mounted above the driver's eye sight and has the capability for the following actions:

a. Sending an alert

b. Send or receive voice calls

c. Sending SOS messages, including the following:

(i) Breakdown notification

(ii) Request for ambulance

(iii) Notification of accident

(iv) Notification of a traffic jam

(v) Notification of a fire on the bus, and

(vi) Request for a voice (Call Request)

The AVL utilises the Global Positioning Satellite system as well as the data and voice communication is established over standard cell phone through GPRS. In addition, the VMU will display messages for driver notification, including the following:

(i) Harsh Braking

(ii) Harsh Acceleration

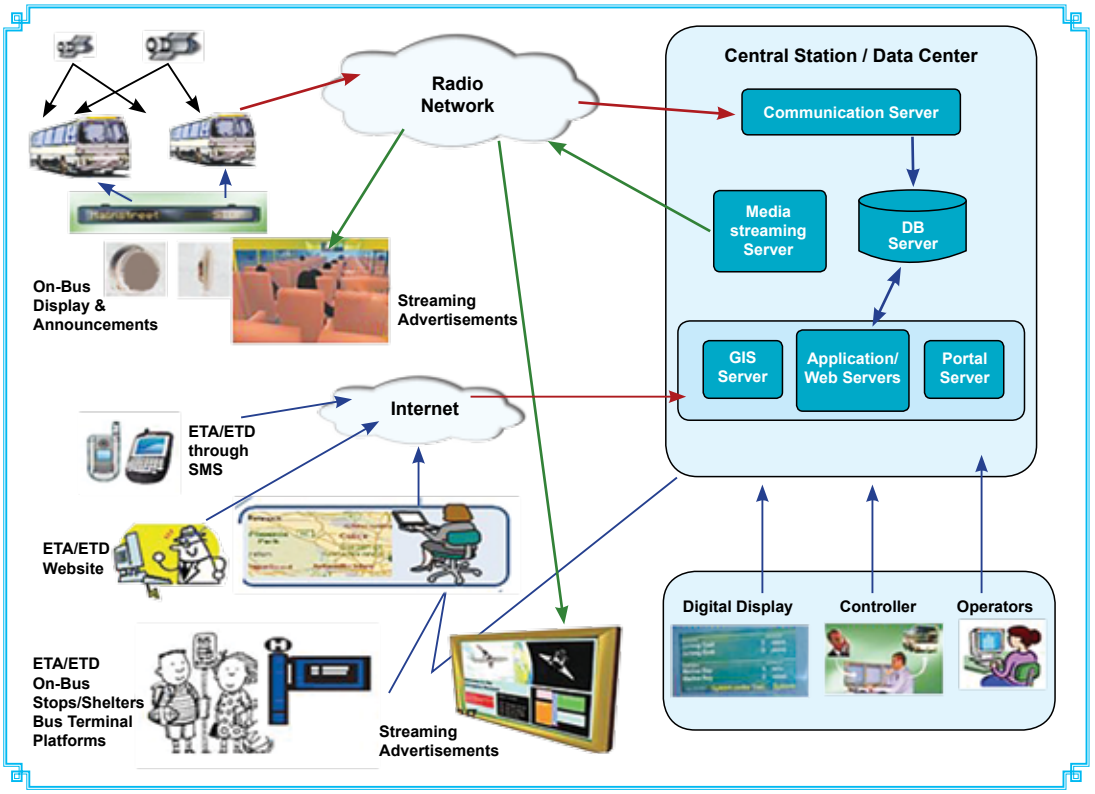



**Figure 4.7: ITS Project and its System Architecture in Mysuru**

(iii) Missed Call

(iv) Generic Message (to be developed)

The ITS project and its System Architecture is shown in Figure 4.7.

KSRTC had aimed for large number of performance improvements through deployment of ITS, which are generally,

1. Customer Satisfaction
2. Modal Share
3. ITS Commissioning and Performance
4. Schedule Adherence
5. Time Savings
6. Bus Ridership
7. Operating Cost
8. Revenue Earnings
9. Safety
10. Environmental Impacts

KSRTC has put in the pioneering efforts for the implementation of ITS based operations with a goal to reap the benefits for all the stakeholders as follows:

Commuters - Ensure Modal Shift with proper information dissemination through ITS solutions.

Operational Staff - Ensure operational governance, effective handling of exceptional incidents and commitments to commuters.

KSRTC Management - Increased revenue through increased ridership and reduction in operational and maintenance cost.

Policy Makers - Contribute to resolve traffic congestion and reduce green house gases.

The implementation of ITS based operations was initiated in 2012 itself, when a baseline survey was carried out for the KSRTC services in the city of Mysuru with the various parameters of customer satisfaction. Similar study was undertaken in January 2018, after 2 years of initial stabilisation of ITS operations in September 2015 and further refinements in next two years. The results are shown in comparison to the baseline data (2012), as given in Table 4.2.

KSRTC is able to improve on customer satisfaction levels (when compared to the baseline data of 2012) due to deployment of ITS. 16% of Non-KSRTC commuters have shifted to KSRTC, and they have

| Measures of Customer Satisfaction | Percentage of Commuters Satisfied with KSRTC Services (in %) | |
|---|---|---|
| | Baseline, in 2012 | After Stabilisation, in 2018 |
| Believe on KSRTC buses | 78.9 | 84.3 |
| Bus fare | 71.1 | 86.2 |
| Travelling time | 81.1 | 84.6 |
| Frequency of buses | 84.9 | 89.4 |
| Behaviour of conductor and driver | 77.8 | 83.1 |
| Driver stopping at place earmarked for bus stops | 74.6 | 81.9 |
| Driver stopping at every bus stop | NA | 77.4 |
| Driving quality | NA | 85.2 |
| In-Bus announcements | NA | 90.3 |
| Information on bus timings | NA | 88.3 |

**Table 4.2: Comparison of Various Parameters of Customer Satisfaction in 2012 and 2018 for KSRTC Buses in Mysuru**

stated that it is due to ITS implementation. There is an increase in total number of passengers carried by KSRTC in a year in comparison to the baseline survey (2012), where the ridership increase is almost 11.9%.

In the present day environment of multi-modal transport (though not coordinated or integrated), to achieve increase in the modal share is extremely difficult for conventional stage carriage bus system. Any single or a combination of the following reasons can be attributed to have an impact on KSRTC's modal share significantly, in spite of huge benefits due to ITS implementation:

- Introduction of Radio Taxis (e.g. Ola/ Uber) where a commuter can get a ride in a passenger car at his doorstep. There are around 4000 taxis and 2000 Auto Rickshaws are integrated for Ola. In addition, aggressive marketing with various schemes and discounts attract the users
- There are 9000 registered card holders with approximately 800 users per day for Bike-Share services with 52 different docking stations in the city
- In the intervening period number of private cars has increased by 87% and two-wheelers by 70%, while the KSRTC buses in Mysuru has increased by 10% only
- Changed activity pattern due to modern life-style also eliminates large number of trips

ITS implementation has evolved as a successful mission for KSRTC from its initiation in 2012 to the present day. This pioneering endeavour of KSRTC Mysuru has to be sustained successfully by constantly improving technology, people, processes and the deliverables. Technology keeps changing with every passing day, as such KSRTC needs to upgrade some of ITS features already implemented and also bring in new systems to improve the benefits for all stakeholders. There has been an increasing trend regarding the use of MITRA website for ITS operations, and therefore, KSRTC must ensure constant updating of the web portal to make it more user-friendly as it is a powerful tool for reaching out to wider sections of the society and attract more ridership.

## 4.3. Intelligent Transit Management System (ITMS)

### *4.3.1. Surat City*

Surat is a fast developing city (second largest in Gujarat) and has numerous traffic problems which increase along with its growth. To solve these, Surat Municipal Corporation (SMC) has embarked upon a plan for a city wide integrated platform - Intelligent Transit Management System (ITMS) - for its various transportation needs.

***The Overall System:***

ITMS is expected to enable SMC to meet its objectives of enhancing service standards, optimizing planning and operations, integrating transit systems and bringing about a paradigm shift in the quality, availability and consistency of its services. The system, when commissioned fully would help SMC to automate its operational processes with respect to mobility management and with noticeable economic benefits and convenience to the citizens through reduced journey times and increased reliability, improvements in safety and quality of air, easier service accessibility, increased citizen trust in civic services and better operations management capability. ITMS is expected to manage diverse set of transportation needs for the city, including public transport and vehicles related to civic services like solid waste management, drainage, heavy engineering, emergency services etc.

Some of the key features of the Smart City project are:

- **Enterprise Management System:** to monitor operations and adherence to laid down service levels; Business Intelligence System

- **Automatic Vehicle Location System (AVLS):** to track buses on service lines and provide alerts like route deviation, trip adherence, skipped stops, etc.
- **Vehicle Scheduling & Dispatch System:** Working time directives, shift scheduling, vehicle maintenance scheduling and customer constraints are taken into account for arriving at optimal decisions. The System is to manage the real-time tracking of around 160 BRT buses, 200 city buses and over 500 other departmental vehicles such as solid waste, engineering and emergency services, as well as management of four BRT bus depots, the delivery of real-time travel information about bus service numbers, arrival/departure times, unplanned and scheduled changes etc for commuters through over 100 passenger information displays installed at the BRT stations and over 800 displays installed at city bus stations in Surat.
- **Incidence Management system (IMS):** helps streamline incidence management in cases like vehicle breakdown, accident, etc; optimizing response times by providing GPS-based dispatching and navigation assistance to the concerned vehicles such as ambulances, cranes, fire engines and police vehicles
- **Depot Management System (DMS):** Manages all bus/ driver information; facilitating schedule management and allocations of the same
- **Passenger Information System (PIS):** This is the central module, which manages all data from buses, GPS units and pushes it to PIS/ mobile app/ website/ call centres, etc. For ensuring the smooth operations along the managed routes, alerts regarding potential delays due to unforeseen conditions such as traffic congestion or breakdowns are sent to the stakeholders from the system
- **Command and Control Centre (CCC):** provides overall management, ensures smooth ITMS functions by coordinating with relevant stakeholders. This center will house various departments/entities involved with managing city traffic and mobility like BRTS, City Bus, Traffic Police, RTO, Fire, Emergency Services, etc. IT-enabled applications will help all the concerned agencies to co-ordinate and support each other for smooth traffic operations
- **Data Centre:** ITMS has its own data centre comprising switches, servers and storage systems, which are specifically designed for the ITMS project
- **Signalling System:** A large number of traffic signals and surveillance cameras have been established. Surat police department has also implemented a centralized command center at Police Commissioner's office to which the various surveillance and other cameras are connected. The new traffic management system should be equipped with red light violation detection system (RLVD) so that violators can be identified and penalized. According to sources, the new system will also be equipped with upgraded infra-red cameras from CCTV cameras to make them effective during the night. Vehicles like fire brigade and ambulances will be equipped with GPS systems and integrated with traffic signals to create a green corridor in the route of these vehicles during emergencies. Based on the suggestion of traffic police, traffic signals and CCTV cameras will be equipped with SMS system so that the violator will be sent an SMS immediately on violation of traffic rule. Around 267 traffic junctions have been identified where the smart sensors will be installed along with 398 high-density CCTV cameras. The virtual loop cameras of this intelligent traffic signal system would constantly read the density of traffic and adjust the green/red light duration accordingly to ensure there is more of red light on directions which have lesser vehicular density and more of green for routes having greater number of vehicles. These smart traffic signals will allow the free flow of vehicular traffic from one junction to another. This system

would also ensure red lights on all directions to facilitate movement of pedestrians, with hooter alerts. Around 614 CCTV cameras fitted on the traffic junctions will be added in the system. Apart from smart traffic signalling system, the integrated system will also catch the offenders flouting the traffic norms like jumping the signals, over-speeding, driving without helmet and seat-belt etc. and send traffic memo and challans to their residence addresses

- **Automated Fare Collection System (AFCS):** It will be possible to manage the system centrally, simultaneously extending a package of transport options to citizens

The implementation of the above systems is being done in two stages: The basic infrastructure which includes the Central Control Centre and the automation of the BRTS forms part of the first stage, and the integration of the city bus operations and other department vehicles such as emergency services and other civic services form the second stage. Integrated Traffic Control System (ITCS) is in full swing and it is likely to be completed by December 2019.

Some other initiatives being implemented (shown in Figure 4.8) are as below:

- **SMAC (SMArtCity) Center** is envisaged as an administrative control center for the city of Surat for effective and efficient delivery of all civic services, operating in four layers. This center will collect functioning information of all the departments on real time basis. Automated

SMAC

Internet on Board


Integrated Payment System

ERP

**Figure 4.8: Implemented ITMS for Surat City**

sensors and systems will send various data sets to the SMAC Center, which are analysed centrally. SMAC Center will play an important role in providing real time information about civic facility utilization in the city. It will help all the departments in maintaining civic service delivery standards on day-to-day basis

- **Integrated Common City payment System:** This will be through a Co-Branded Multi-Application Contact less Smart Card, Surat Money Card. It is envisioned to offer wide range of civic services to citizens with convenience of using single SMART card only. In the first phase 16 services have been identified which include transport, health, education, nutrition, affordable housing, shop and other licenses, library, sports and recreational facilities etc.
- **Internet:** SMC wishes to provide WiFi service to the citizens covering important public places. Apart from this, SMC wishes to have the citywide Fiber to Home connectivity, which will be useful in providing reliable connectivity with high bandwidth, meeting the present and future requirements
- **ERP & GIS Platforms:** The ERP for critical Municipal Operations is a framework for integrated solutions on a common technology platform to address process automation needs of Surat Municipal Corporation. It will be a modular framework consisting of several integrated applications built for security and scalability. Applications will be assembled on a common technology platform that addresses institution wide process automation
- **Incubation/Start up Centre:** A Start-up & Incubation centre is proposed to train the semi-skilled/ skilled job seekers in various trades and to provide necessary information though single window clearance to promote start-ups

### *Key Outcomes:*

Many developments under the project have already been set up. Around 115 BRTS buses and 200 city buses are being tracked using ITMS. A year and half ago, nearly 25,000 commuters used to travel by the BRTS per day, which is now nearing 2 lakh passengers per day. In addition, 154 BRTS stations and more than 400 city bus stops have been integrated with ITMS. BRTS and city buses are now available with an average frequency of 8-10 minutes and there is increased information about public transit covering BRT buses and city buses, to citizens with help of mobile app and public website. Inaugurated in June 2016, SMAC centre uses ICCC platform integrated with a GIS platform with 12-13 layers for the project. This centre is linked with the CCTV project of Surat city police department that has over 650 CCTV cameras at different locations. An additional 1,000 CCTVs, proposed to be set up by the SMC soon, will also be linked to this centre. A typical view of such SMAC (SMArtCity) Center is shown in Figure 4.9.

In the medium to long run, the implementation of ITMS is expected to improve public transport connectivity across the city – increased number of buses on BRTS as well as city bus routes, in accordance with demand analysis through ITMS. Increased ridership and increased usage of public transport along with reduction of travel time owing to dedicated BRT corridors managed through ITMS will be great advantages. The Surat Municipal Corporation has bagged three awards

**Figure 4.9: SMAC (SMArtCity) Center**

from the Ministry of Housing and Urban Affairs for the Best Integrated Mass Transit Project, Best Intelligent Public Transport Services and Commendable City in Urban Transport Initiative. SMC, which has launched 70 Smart City projects worth ₹ 26.90 billion in June 2015, is expected to complete them by 2020. The civic body has already completed 28 projects worth ₹ 3.65 billion, whereas work is under progress for 31 projects worth ₹ 18.82 billion. Around 11 projects worth ₹ 4.43 billion is under tender process.

### *4.3.2. Rajkot City*

Systems similar to those being set up in Surat are also being implemented in Rajkot City.

## 4.4. Bus Rapid Transit System (BRTS)

### *4.4.1. Ahmedabad Bus Rapid Transit System: Janmarg Limited*

Ahmedabad is the seventh largest city in India, while being the largest city and capital of Gujarat, India. A city with 6.36 million people in 2011 is likely to have 11 million inhabitants in 2035 and is likely to grow from 520 sq.km to 1000 sq.km in size. Eleven bridges connect the eastern part of the city with western part across Sabarmati river. The organized public transport by Ahmedabad Municipal Transport Services dates back to pre-independence era, but was plagued with inefficiencies and resource crunch and could operate only 450 buses in 2005 with daily ridership of about 350,000, which continued to decline in favour of Auto-Rickshaw and other personalised modes.

Bus Rapid Transit (BRT) system has been adopted world over due to its special characteristic of providing a road based mass transit system in support of sustainable transport for urban areas. Dedicated bus lanes separate BRT buses from mixed traffic, allowing them to travel more quickly through a city. The dedicated bus lanes have reduced interaction between buses and other vehicles, minimizing the risk for traffic accidents.

The Government of Gujarat had declared 2005 as the "Year of Urban Development" (Shaheri Vikas Varsh). During the year Gujarat Infrastructure Development Board (GIDB), Ahmedabad Municipal Corporation (AMC) and Ahmedabad Urban Development Authority (AUDA) jointly drafted a comprehensive urban mobility plan including the implementation of Bus Rapid Transit System (BRTS). CEPT University was assigned the work of preparing the Detailed Project Report (DPR) for implementation of BRTS and later in November 2006 it was approved under Jawaharlal Nehru National Urban Renewal Mission (JNNURM), which was first of its kind in the country.

Ahmedabad BRT with name as 'Janmarg' or 'the people's way' began its operation in October 2009. It has grown from a 12 km network with 18,000 customers to a 101 km network in mid-2018 (with 89 km as dedicated corridors) with daily customer base of 200,000. The salient features of Janmarg (BRT) are:

(i) a closed BRT system with median bus stations;

(ii) specially designed buses with right hand side doors and bus floor and bus station platform heights matching;

(iii) a complete revamp of the right of way to include cycle tracks and pedestrian facilities;

(iv) an operating speed of 24 km/h enabling faster commuting; and

(v) off-board fare collection

As of June 2018, following are the currently operational routes; eleven in both directions and two in circular direction; and one shuttle serving together a total of 163 BRTS stations and cabins.

i. Ghuma ↔ Maninagar

ii. Science City Approach ↔ Odhav Ring Road (via Delhi Darwaja)

iii. RTO ↔ Maninagar (via Anjali)

iv. Zundal ↔ Commerce Six Roads

v. Vasna ↔ Naroda (via Narol)

vi. Narol ↔ NarodaGaam

vii. Vishwakarma College (IIT) ↔ Narol (via Kalupur)

viii. ISKCON Cross Roads ↔ Naroda (via Kalupur)

ix. Gota Cross Roads ↔ Maninagar (via GeetaMandir)

x. Townhall / MJ Library ↔ Odhav Ring Road

xi. RTO ↔ Hatkeshwar

xii. RTO → RTO (clockwise, via Kalupur → Anjali)

xiii. RTO → RTO (anticlockwise, via Anjali → Kalupur)

BRT system was planned to be developed in phases: Phase I was with 5 corridors of total length 58 kms, and Phase II has been with 6 corridors of total length 30.5 kms (having 4.5 kms elevated). The BRT lanes are two median lanes 3.65 to 3.75 m wide. Other motorised traffic lanes are 9.25 to 10.75 m wide depending on total ROW, and the NMV and pedestrian ways are kept as 2-2.5 m and 2 m wide respectively. Planned corridors to serve the various land uses in the city are shown in Figure 4.10.

BRT stations are 38 m long and 3 m wide median bus stops for a closed system with access control and level boarding with off-board ticketing system. Buses are specially designed with 1.2+1.2 m wide boarding-alighting central doors, 900 mm floor height with 90 passenger capacity. It has a mixed fleet of air conditioned and non-air conditioned buses. It has 250 Euro IV compliant diesel and CNG buses, 200 of which are AC buses. Currently a fleet of 50 electric midi AC buses are being inducted.

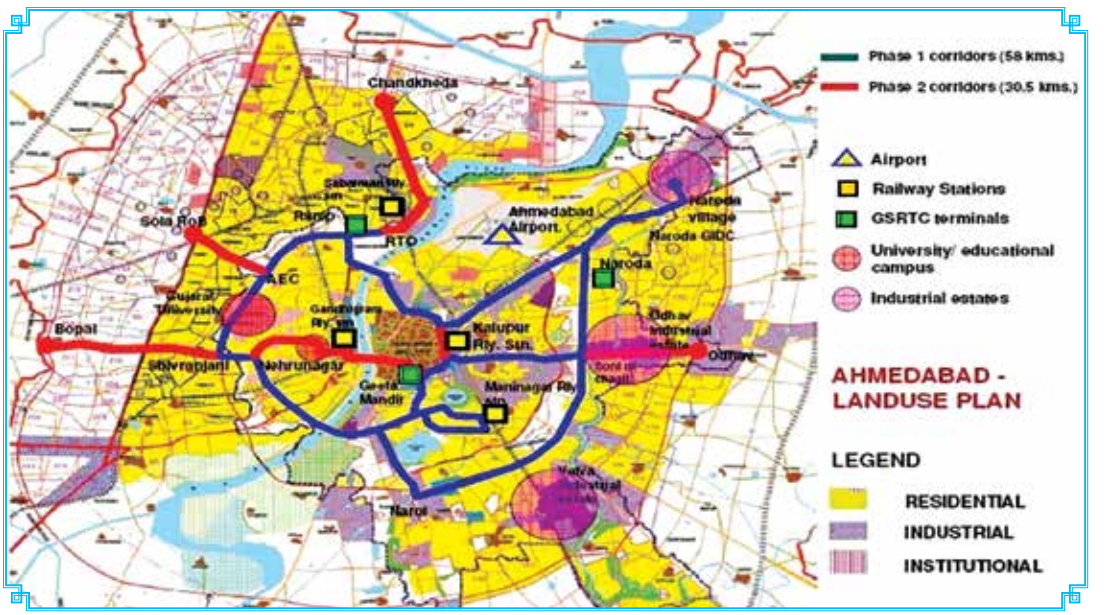



**Figure 4.10: Planned BRT Corridors to Serve Different Land Uses in Ahmedabad**

The ITS controls adopted for the BRT are as follows:

(i) Operations Control

(ii) Automatic Vehicle Tracking System

(iii) Electronic Fare Collection

(iv) Real-time Passenger Information System

(v) Traffic Management (ATCS)

The system runs on Integrated Transportation Management System (ITMS) which includes Advanced Vehicle Location System (AVLS), Fleet Management System (FMS), Automatic Fare Collection System (AFCS), Passenger Information System (PIS), Passenger Announcement (PA), and Vehicle Scheduling and Dispatching (VSD) system. As a part of Intelligent Transit Management System (ITMS), an app based and QR code powered ticketing system was introduced in June 2017. The integrated IT system working for Ahmedabad BRTS is shown in Figure 4.11.

For the first three months of operation, the project ran free of cost. During these three months, the AMC sought for help and suggestions from special groups of opinion makers-students, professors and teachers, journalists, top industrialists of Gujarat-and gave them free rides. Most of the ideas received were used. The way the lanes have been drawn, the bus stands designed and the manner in which the system is managed by a computerised traffic management and signal control system from a chamber in the AMC office is proof of its success. The overall BRT network in operation at present is shown in the Figure 4.12.

Janmarg has made several innovations in the planning and designing of the system including a fully 'pedestrian and transit' only street section at one location and a one-way bus lane to manage narrow right of way. At a larger level, Janmarg has demonstrated that BRT system can work in India. Janmarg looked at other BRTS in cities around the world and adapted their best practices in the context of Ahmedabad. Even a level boarding and

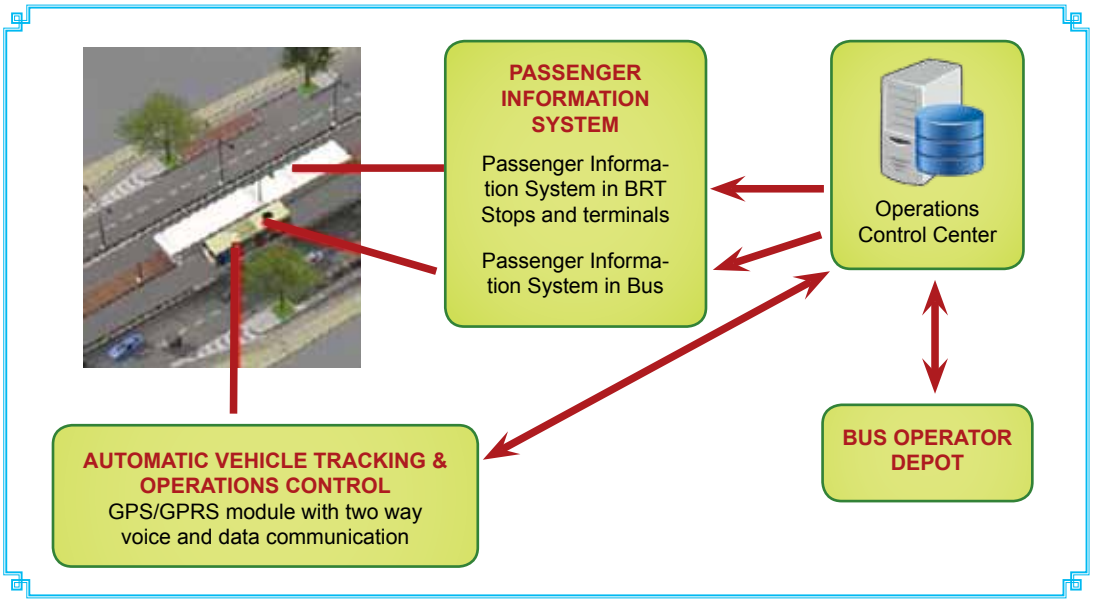



**Figure 4.11: Integrated IT System for BRT Network in Ahmedabad**

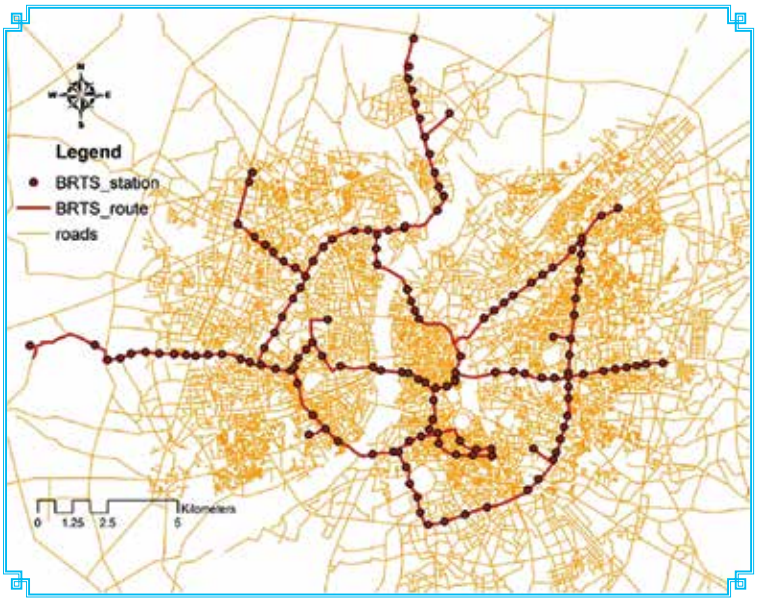



**Figure 4.12: BRT Network in Ahmedabad**

alighting with matching bus floor was adopted in the system as shown in Figure 4.13.

A big factor in the success of Janmarg has been the positive role played by citizens. The Ahmedabad Municipal Council (AMC) held regular press briefings on the planning and designing process, public exhibitions and presentations, responding to all suggestions and recommendations. The success of the BRT system has also led to an overall improvement in the service quality of the Ahmedabad Municipal Transport Service (AMTS). All old diesel buses with obsolete technology have been replaced with compressed natural gas buses. AMTS has added more than 900 new buses over the last four years. The routes for these buses are now being operated as feeder services for Janmarg.

Ahmedabad BRT is a PPP based project. Ahmedabad Janmarg Limited (AJL), the parent company which governs BRTS operations in Ahmedabad, was constituted as a Special Purpose Vehicle by Ahmedabad Municipal Corporation, Ahmedabad Urban Development Authority and Government of Gujarat. The Public Sector is represented by Ahmedabad Janmarg Limited (AJL), a Special Purpose Vehicle (SPV) chaired by Municipal Commissioner. The Private Sector involvement is through ten PPP arrangements, such as

(i) Bus procurement

(ii) Operations and maintenance

(iii) Integrated information system including automatic ticketing and vehicle tracking system

(iv) Supply and service contracts for bus station sliding doors and turnstiles

(v) Housekeeping and cleaning of bus stations

(vi) Management of pay and park facilities

(vii) Lease of advertisement rights

**Figure 4.13: Level Boarding-Alighting in Ahmedabad BRT System**

(viii) Development of foot over bridges

(ix) Development and maintenance of landscapes

(x) Maintenance contracts for bus stations (Civil Works), lighting of bus stations and corridor, monitoring and maintenance of BRT corridor (Civil Work), signage, etc

Janmarg has been a catalyst in the rejuvenation of Ahmedabad. The entire network has been planned in a manner that ensures that almost all major destinations are covered. The appeal of the system has reached previously under-served social groups. For example, the afternoon hours, which are the off-peak, have seen a rise in female travelers; almost 40 per cent of commuters in the afternoon are women. Dedicated buses for women were also introduced in January 2016.

Overall, the project may be treated as a success story in the field of urban public transport and it may be replicated in other cities in India and the world. The reasons for the success of Ahmedabad BRT may be attributed mainly to the good institutional structure maximizing quality of service and minimizing the cost.

One application implemented in Advanced Public Transport System (APTS) area in GPS vehicle tracking system in public transport buses (Bengaluru, Chennai, Indore) to monitor vehicle routing and frequency so that passengers do not have to wait long hours for a bus. The objective is to provide Global Positioning System based passenger information system to help passengers utilize their waiting time at bus stops more efficiently as well as to reduce the uncertainty and associated frustrations. Display boards with high quality light emitting diode in wide view angle are provided at bus stops so that passengers can read the information. It displays the number and destination of the approaching bus, expected time of arrival.

## 4.5. Metro Rail Systems

### *4.5.1. Delhi Metro*

Delhi has experienced phenomenal growth in population in the last few decades. Its population increased from 1.47 million in 1951 to 13.7 million in 2001 and 16.3 million in 2011.Today, Delhi's population is close to 20 million. City has also spread physically to distant borders in all directions. The number of vehicles has spiraled physically increasing from a little more than half a million in 1991 to 7.2 million in 2011.

Planning of metro at Delhi was started as early as 1969-70 when Central Road Research Institute, an Organisation of CSIR, mooted a proposal of mass rapid transit system network for the city. Subsequently, number of proposals of Mass Rapid Transit System for Delhi City were made but none finalized. In 1984, Master Plan of Delhi 2001 recommended a multi model transport system comprising of 200 km of light rail transit system, 10 km of tramway, an extension to surface rail system and extensive road network.

A major threshold was however achieved only in 1990 by preparing the feasibility report of integrated multi model mass rapid transport system for Delhi. In 1991, Government of National Capital Territory of Delhi commissioned M/s RITES to prepare the Detailed Project Report and tender documents for the first phase of the project. The proposed modified first phase of Delhi Mass Rapid Transit System was finalised with its length of 55.3 km.

Target for commissioning the entire phase-1 of 55.3 kms was set as March 2005. However, adherence of target dates depended on finalization of funds and investment decisions by March, 1996.

A decision to set up a company was taken for the implementation of MRTS project, with its

Chairman and 5 full time Directors including Chief Executive Officer (Managing Director). The company was registered on 3rd May,1995 under the Company Act. This company was to have equal equity participation by the Central Government and the Government of Delhi. This was a unique structure for a Public Sector Undertaking Company, used for the first time in India.

This was one of the landmark decisions to have a company with 50:50 shares of two Governments so as not to vest full powers into either of the two Governments, but full power to Board of Directors.

It is a fact that metro is a highly capital intensive mode of transport and political will and determination to take up such projects is imperative. DMRC started out with a bold realization that the technology needed to build a world class metro was not available within the country and therefore, it needed to be sourced from outside.

The continuous concern and care of DMRC to the under mentioned areas has ultimately led to DMRC's success.

**Re-defining Construction Values –** Beyond leaders, beyond planners, beyond everything, a project that is meant for the people is first and foremost answerable to the people. At DMRC, this answerability was enshrined in the work culture of the Organisation at the very outset. To construct cleanly, DMRC always aimed to keep the beneficiaries of the project in the know of things, to work without endangering the ecological balance, to work without being an impediment and a hazard to the population and so on. With so much to answer for, DMRC went on to complete the first section of the first phase of Delhi Metro by setting new standards of Organisational behaviour, public relations, construction management and social participation that the nation had never seen before.

**A Care for the Environment –** The construction of Delhi Metro was one of the most ecologically challenging urban projects ever undertaken in the country. At DMRC, this was considered to be a sphere of utmost importance from the very outset. Today, a detailed Environmental Impact Assessment done in the beginning of a project ensures that there is minimal negative environmental impact of the project during the construction stage. The corporation also follows a stringent Environmental Quality Management Manual that provides comprehensive guidelines for keeping the construction impacts to a bare minimum. Besides continuous monitoring on air quality and noise levels, it includes the use of silencers on construction equipments, minimizing the vibration and rattling of machinery, the erection of temporary physical noise barriers and non-intrusive scheduling of truck loading operations. 30% of the trees in the alignment have been successfully saved and full care is taken to ensure compensatory forestry. DMRC stands committed to plant ten trees for every tree cut during implementation of the metro rail project. The corporation left no stone un-turned in transplanting rare and eco-friendly trees at new locations. DMRC has its own environmental policy which helped to adopt environmental friendly construction methods, create assets

that are aesthetically appealing, conserve and enhance green cover, make all efforts to create environmental awareness and strive for continual improvement in our environmental policies.

**Creation of Safety Awareness –** Building a metro rail service involves the physical challenge of working at different depths and heights. In a city where a simple life safety gear like a driving helmet for a two wheeler is still considered by many as something being forced upon, it is not surprising that it took round the clock surveillance to ensure that safety norms were followed at every point during the early stages of construction. DMRC had to really work relentlessly to ensure that all workers and site staff realized the life saving importance of safety gear and wore boots and helmets as a part of regular work discipline followed by metro network in other world cities. Frequent inspections and test schedules were undertaken and safety clothing and protective gear like helmets, goggles and gloves were provided. The fire safety of the network, during and after construction was ensured by top quality sprinkler systems, fire hoses and portable fire extinguishers.

**Construction Management –** Corporation ensured the minimal traffic disruption to the public by planning efficient traffic diversions and barricading. Prominent signages were put up at all construction sites. In thickly populated areas, directional light shielding was done to confine working lights to the work area as far as possible during the night time construction. At every step, DMRC coordinated with civic bodies to control and restore traffic, water supply, electricity and communication lines affected by construction activities.

**Community Interaction –** Corporation felt that ultimate success of the metro projects lies in keeping the public informed. Right from initial stages of planning and construction, the public relations department of the Corporation was busy in building an interactive relationship with its future commuter base. A prime component of this education and orientation plan was to organise Community Outreach Progammes. Continuing this programme along the rail corridors of metro, DMRC officers met the local population to keep them informed about construction schedule and its envisaged temporary effects on day to day life. Any grievance of the people was promptly heard and solution found in real time. As a part of the drive, to spread awareness among the public in Delhi, DMRC organized mobile exhibitions on a regular basis in various schools, colleges and other prominent locations. The education programmes were carried forward in a very innovative manner through the scripts and staging of NukkadNataks or street plays with the aim to develop understanding, respect and proper usage of the metro services. Time and again, DMRC came up with innovative communication strategies hinged on the highest ideals of truth, honesty and transparency.

**Metro Network made Attuned to the Physically Challenged –** Delhi Metro also set the trend for the entire nation in terms of its design sensitivity to the needs of the physically challenged and the elderly. The human face of design and DMRC's respect for the dignity of the physically challenged comes across through the implementation of wide ranging measures. All platforms have rows of dotted guiding blocks near the edge and the platform surface is made of slip resistance materials. All stations have elevators with features like audio announcement of floor arrival and relief panels.

**Core Strength –** DMRC's core strength is the work culture. DMRC's management nurtured the three pillars of the strength from the day one namely, Knowledge, Integrity and Punctuality. Undoubtedly, the most energetic driving force at DMRC has been the new sense of confidence instilled by a new work culture that has flowed like an elixir from the top to the bottom of the

DMRC's Organisational pyramid. The realization was starkly clear that, "Great projects are not just built by great technology, they need the mortar of human excellence, integrity and uncompromising endeavour too". Accepting that the first task was to build an Organisation with the right attitude and work culture, each individual was carefully chosen on the anvil of personal capability and integrity. The Organisation was lean and effective to avoid dissatisfaction and to get the optimum utilisation of the manpower. That remains the motto even today. Along with the trend of quality and integrity, great importance has been given to transparency of thought and action across all levels and respect for deadlines. Punctuality has always been a foundational asset for the new wok culture. From being at work stations and worksites on time to treating every deadline as sacrosanct, respect for punctuality has been a major productive force at DMRC.

In every office and work site of DMRC, prominently displayed Reverse Clocks were set to the targeted date and the challenge was taken head on. The challenge of keeping to the cost estimates, the challenge of setting project management benchmark and the challenge of giving India the world's most advanced metro rail system, was the ultimate goal of DMRC's management and every employee.

With the due and continuous importance to the areas as above, the factors for Delhi Metro's Success are reiterated as below-

i. Political will to implement the project;

ii. CEO of the DMRC being Technocrat and Leading the company with accountability and responsibility;

iii. Unique structure of Delhi Metro Rail Corporation as a company;

iv. Public support;

v. Least disturbance to Road traffic with excellent traffic diversion plans;

vi. Alignment of Metro Corridors was planned so as to affect minimum private properties.

vii. Firming up of funding plan and sources to fund the entire cost of the project;

viii. Judiciary support.

ix. Fast and on the spot decisions;

x. Full Support by all the Urban Local bodies

xi. Belief in three pillars of strength namely, knowledge, integrity and punctuality

With the strength and support as listed above, a dream was revisited on 24th December, 2002 with the inauguration of first section of metro with its length of 8.3 km between Shahdara and Tis Hazari by the then Hon'ble Prime Minister of India Shri Atal Behari Vajpayee.

Subsequently, DMRC completed balance of phase-I and Phase-II of metro network with the details as under:

- Phase-I – 65 kms. Cost US $ 2.5 billion. Completed in 7 years and 3 months (2 years & 9 months ahead of schedule). Phase-I was completed by September 2005
- Phase-II – 125 kms. Cost US $ 4.3 billion. Though double the length, completed in half the period taken for Phase-I, and five months ahead of schedule. Phase-II was completed by October 2010

Both the Phases were completed without cost and time over runs

- Implementation of Phase -III was also started in February 2011 and 183 km is already commissioned with the total network on date as 373 kms. Balance 5 Kms of Phase - III is under advance stage of implementation and likely to be commissioned by June 2019.The Total cost of Phase III will be 7.8 billion US $
- 62 kms. of Phase IV of Delhi metro has also been sanctioned recently by Government of India with its cost as US $ 3.5 billion. The work at site is likely to begin by the end of the year 2019 and be completed by December 2024

DMRC is now operating 373 kms of metro network with daily Journeys numbering 5.5 Millions and with 351 Train sets.

Today, DMRC stands on a very different threshold where it is looking out to the world of opportunities as a turnkey consultant for setting up of metro network within borders of the country and beyond. Now, with the DMRC being equipped with total expertise for executing projects, it has emerged not just as a nodal agency for the metro revolution in the country, but also as a front runner in metro consultancy worldwide. Now DMRC is well known for its capabilities as a consultant, for preparation of feasibility studies and project reports, identification of the right experts, interfacing of contractors and consortium suitable for implementing the projects, providing technical assistance and total project supervision. DMRC is today, busy with feasibility studies and detailed project reports and implementation of Phase-IV of Delhi Metro.

The biggest achievement however, has been the internationalization of India's capabilities in the sphere of metro networking and construction. The successful construction of the first section of the first phase of Delhi Metro Rail and the steady progress of the rest of the projects has invited inquiries from the cities outside the country not just for DMRC, but also its contractual agencies and suppliers associated with DMRC's projects.

Today, Delhi Metro network is one of the fastest developing networks in the world, except for China.

In the end, it may only be said that the projects of this magnitude may only be developed with committed Chief Executive Officer, an efficient Organisation with honesty, Integrity, punctuality, transparency, commitment, public concern and well tied finances. Above all, the political will is very necessary.

# AREAS RECOMMENDED FOR ATTENTION


**Public Bicycle Sharing scheme**
Under this concept, commuters are able to take bicycles on rent from a residential area and travel to the nearest metro station and then again rent a bicycles from a departing metro station to the nearby localities.

# 5. AREAS RECOMMENDED FOR ATTENTION

Keeping in view, the coverage in the various sections of this report, dealing with different aspects of Urban Transportation, the issues requiring attention are identified under four heads, namely, Organisational Issues, Policy Issues, Intelligent Transportation Systems (ITS) Issues, and, Engineering Issues. It is noteworthy that during the few years immediately preceding the study being reported, some of what is being recommended has been attempted in the country with a reasonable degree of success. However, this has happened in a very limited way, and there is a need to cover much wider ground.

Thus, whereas clearly, there are a few areas for which impetus has to be provided to come out of the 'as is' mode, and, for accelerating the pace of implementation, there are others for which action is to be initiated. The latter are grouped under Section 6.

## Organisational Issues

There is a clear need to avoid multiplicity of responsibility and controls in developing/ implementing various aspects of urban traffic & transportation systems. Whereas, broad policies have to emerge from the central government, the baton has then to pass on to the state governments and finally to rest with city administrations. Considering the vital importance of metro rail development for easing out the urban traffic problems, it is imperative this is provided with greater independence rather than being encumbered by the norms, practices and controls of the conventional railway systems. Similarly, other mass transport systems (high capacity modes) are also to be developed based on the projected corridor level travel demand in the cities.

Implementation and functioning of Unified Metropolitan Transport Authority (UMTA) and Urban Transport Fund (UTF) for their true objectives can facilitate much needed institutional reform and integration in urban transport development. UMTA/UTF can formally plan for the multi-modal transport environment, duly exercising their unifying authority, and recognising multi-modality possible in different environment of urban space. The states have to enact and empower the UMTA to be in the saddle with complete legal backing. Furthermore, it is imperative that the Government of India consider, legislation in the form of a Urban Transport Act to strengthen UMTA and its implementation in the states.

An all-India cadre should be set up consisting of Traffic & Transportation personnel, including ITS experts in various fields (planning, IT, utilities, mechanical systems, etc.) for faster and more efficient delivery. There is an increasing need to deal with enforcement issues and the Law & Order machinery should be strengthened and modernized to take care of this effectively.

## Policy Issues

National-level policies, to drive the multi - modal transport environment, will have to be framed for, promoting and implementing integrated Public transportation systems such as metros and BRT, with special provisions for NMT (bi-cycles and pedestrians etc.) for various urban centres in a planned manner expeditiously. Likewise, a policy framework is needed to set up a National database of all motorised vehicles covering smart number plates and all driving licenses adopting smart card driving licenses, etc. and, real time

traffic accident data capture and management. Policy is also to be evolved for introducing greater automation and follow an on-line approach for parking facilitation, and for issue of driving licenses as well as issuing challans.

## Intelligent Transportation Systems (ITS) Issues

Technologies should be developed and implemented in a planned, integrated manner across urban centres, using standardised techniques and systems across India to share knowledge, experience and costs, starting with stand-alone systems which can start yielding results quickly, after due public education campaigns. This can be followed up with efforts towards wider use and networking, with, automation to be introduced into Toll Collection, Traffic Control Systems including detection of traffic offences and issue of challans. Universal contactless Smart cards valid across all public transport systems should be utilised for fare payment. Likewise, Integrated Information Systems or City Traffic App for multi-modal transport system in a city, giving map-based information for transit from point A to point B across all available systems, including IPT systems, should be developed.

## Engineering Issues for Infrastructure

Urban structures catering to traffic shall be planned, designed and constructed, employing Professional Engineers (PE) to ensure safety and sustainability with an eye on aesthetics, rapid construction with maximum possible prefabrication, minimum disturbance to underground services (after their detection using all available geotechnical and geophysical methods) and existing traffic. IRC codes should permit necessary deviations in geometrics and loading standards to be applied judiciously for urban situations, which call for it.

Further, in order to facilitate appropriate planning infrastructure for Urban Transportation, it is imperative that the space in cities, both above and below ground, is surveyed and accurately mapped in the digital mode, to be available to planners and the engineering organisations.

# WAY FORWARD

**The 90 m span Foot Over Bridge** for the venue of Commonwealth Games in Delhi is a pre-eminent example of aesthetics and functionality. Aerodynamic excitation of slender structures has been well known for some time. On the other hand pedestrian excitation causing lateral sway has surfaced in recent times. The design of this bridge accounts for these aspects.

# 6. WAY FORWARD

It is envisaged that the report and the areas identified for attention will be assessed by an appropriate body of the Government of India and be shared with the State Governments, who will be involved in a major way in implementing the actionable recommendations. On the basis of Section 5, it is recommended that action be initiated on the following aspects related to Urban Transportation. *The italicized section numbers in parenthesis indicate where more relevant information could be found.*

1. An all-India cadre should be set up consisting of Traffic & Transportation personnel, including ITS experts in various fields (planning, IT, utilities, mechanical systems, etc.) for faster and more efficient delivery *(Sections 3.6.3, 3.6.5 and 3.7.3)*.
2. Considering the vital importance of metro rail development for easing out the urban traffic problems, it is imperative that this is provided with greater independence rather than being encumbered by the norms, practices and controls of the conventional railway systems *(Section 2.5.1)*.
3. National-level policies, to drive the multi – modal transport environment, will have to be framed for, promoting and implementing expeditiously in a planned manner, integrated Public transportation systems such as metros and BRT, with special provisions for NMT (bi-cycles and pedestrians etc.) for various urban centres. *(Sections 3.3.2 and 3.3.4)*.
4. A policy be framed to enable the setting up of a National database of all motorised vehicles covering smart number plates and all driving licenses adopting smart card driving licenses, etc, and, real time traffic accident data capture and management *(Sections 3.6.4, 3.6.5 and 3.7.3)*.
5. Automation to be introduced into Toll Collection, Traffic Control Systems including detection of traffic offences and issue of challans, besides the development of a City Traffic App for multi-modal transport system in a city, giving map-based information for transit from point A to point B across all available systems *(Sections 3.6.2 and 3.6.5)*.
6. IRC codes should permit necessary deviations in geometrics and loading standards to be applied judiciously for urban situations, which call for it *(Section 3.2.9)*.
7. In order to facilitate appropriate planning of infrastructure for Urban Transportation, it is imperative that the space in cities, both above and below ground, is surveyed and accurately mapped in the digital mode, to be available to planners and the engineering organisations *(Sections 2.6, 3.4.2 and 3.4.5)*.
8. Implementation and functioning of Unified Metropolitan Transport Authority (UMTA) and Urban Transport Fund (UTF) and integration in urban transport development. Furthermore, it is imperative that the Government of India

consider for legislation in the form of the Urban Transport Act to strengthen UMTA and its implementation in the states *(Sections 3.3.3, 3.3.4 and 3.3.5)*.

9. A nationwide drive to improve safety on the road has to be taken up in a comprehensive manner, involving all the stakeholders, through appropriate media campaigns, etc as the safety statistics are very alarming and getting worse day by day *(Section 2.3, 3.2.5 and 3.7)*.

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# APPENDIX:
## MODAL SPLIT IN INDIAN CITIES (IN %) FROM VARIOUS REPORTS

**This flyover in Mumbai** crossing Sion Hospital, Kings' Circle - Tulpule Chowk and Hindmata Junctions is a unique example of the initiative taken by the local residents for reclaiming the space below the bridge to ensure against its misuse, under - utilization and encroachment. It serves as a landscaped path and a place to meet and greet.

# APPENDIX: MODAL SPLIT IN INDIAN CITIES (IN %) FROM VARIOUS REPORTS

| City Size Category (Million Population) | City Name | Population in the City (Million) | Walk | Non-Motorised Transport | | Intermediate Public Transport | | Public Transport | Motorised Personal Transport | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Cycle | Rick-shaw | Auto Rickshaw | Others | | Cars | Two Wheelers |
| **>8.0*** | - | - | 22 | 8 | | 7 | | 44 | 10 | 9 |
| **>5.0*** | - | - | 29 | 8 | 1 | 1 | | 47 | 4 | 10 |
| | Mumbai** | - | 12 | 10 | | - | | 60 | | 18 |
| | Mumbai*** | 16.40 | 28 | 5 | | 9 | | 44 | 9 | 5 |
| | Mumbai**** | 17.70 | 27 | 6 | | 7 | | 45 | 8 | 7 |
| | Kolkata** | - | 12 | 4 | | - | | 77 | | 5 |
| | Kolkata*** | 13.20 | 18 | 12 | | 3 | | 57 | 7 | 3 |
| | Kolkata**** | 14.70 | 19 | 11 | | 4 | | 54 | 8 | 4 |
| | Delhi** | - | 35 | 5 | | - | | 40 | | 20 |
| | Delhi*** | 12.90 | 20 | 12 | | 6 | | 43 | 14 | 5 |
| | Delhi**** | 13.80 | 21 | 12 | | 6 | | 43 | 14 | 5 |
| | Chennai** | - | 32 | 16 | | - | | 42 | | 10 |
| | Chennai*** | 6.56 | 22 | 6 | | 9 | | 32 | 9 | 22 |
| | Chennai**** | 7.00 | 22 | 8 | | 8 | | 31 | 10 | 20 |
| | Bengaluru** | - | 46 | 10 | - | - | | 36 | | 8 |
| | Bengaluru*** | 5.70 | 28 | 5 | 18 | 18 | | 26 | 16 | 7 |
| | Bengaluru**** | 8.60 | 26 | 7 | 7 | 7 | | 35 | 8 | 17 |
| | Hyderabad** | - | 21 | 28 | - | - | | 35 | | 16 |
| | Hyderabad*** | 6.34 | 22 | 6 | 7 | 7 | | 49 | 8 | 8 |
| | Hyderabad**** | 6.30 | 22 | 9 | 7 | 7 | | 35 | 9 | 9 |
| | Ahmedabad** | | 48 | 14 | - | - | | 28 | | 10 |
| | Ahmedabad*** | 5.41 | 22 | 14 | 5 | 5 | | 15 | 20 | 24 |
| | Ahmed-abad**** | 5.90 | 22 | 14 | 6 | 6 | | 16 | 17 | 25 |
| **4-8****** | - | - | 25 | 11 | 7 | 7 | | 21 | 10 | 26 |
| **2-5*** | - | - | 29 | 13 | 2 | 7 | | 33 | | 24 |
| | Pune** | - | 28 | 10 | - | 2 | | 38 | | 24 |
| | Pune*** | 3.78 | 24 | 8 | 8 | - | | 12 | 10 | 38 |

| City Size Category (Million Population) | City Name | Population in the City (Million) | Walk | Non-Motorised Transport | | Intermediate Public Transport | | Public Transport | Motorised Personal Transport | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Cycle | Rickshaw | Auto Rickshaw | Others | | Cars | Two Wheelers |
| | Pune**** | 4.2 | 22 | 11 | | 7 | | 12 | 12 | 35 |
| | Kanpur** | - | 72 | 21 | | - | | 5 | 2 | |
| | Kanpur*** | 2.72 | 30 | 18 | | 7 | | 6 | 7 | 32 |
| | Kanpur**** | - | 29 | 19 | | 7 | | 9 | 16 | 21 |
| | Lucknow** | - | 36 | 36 | | - | | 0 | 28 | |
| | Lucknow*** | 2.24 | 38 | 26 | | 8 | | 0 | 4 | 24 |
| **2-4**** | - | - | 25 | 18 | | 6 | | 10 | 12 | 29 |
| **1-2*** | - | - | 30 | 8 | 5 | 2 | | 24 | 1 | 30 |
| **1-2**** | - | - | 24 | 19 | | 8 | | 13 | 1 | 24 |
| **0.5-1*** | - | - | 32 | 10 | 9 | 3 | | 21 | 2 | 23 |
| **0.5-1**** | - | - | 32 | 20 | | 3 | | 9 | 12 | 24 |
| **<0.5 (category 1a)**** | - | - | 34 | 3 | | 5 | | 5 | 27 | 26 |
| **<0.5 (category 1b for hilly towns)**** | - | - | 57 | 1 | | 0 | | 8 | 28 | 6 |
| **0.1-0.5*** | - | - | 38 | 15 | 12 | 3 | | 13 | 1 | 18 |
| **0.5-0.1*** | - | - | 38 | 17 | 13 | 4 | | 11 | 1 | 16 |

*Source: * Tiwari (2011); ** Pendakur 2002 and World Bank 2002; *** Data from various City Development Plans available at http://www.jnnurm.nic.in/ (accessed on 20 January 2014); **** Wilbur Smith Associates, GOI (2007).*
*Note: Figures are in % except where mentioned otherwise*

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**E-rickshaw to boost last mile connectivity:** With a view to provide convenience to its commuters by ensuring last mile connectivity from the metro stations, services of specially designed e-rickshaws with covered cabin and full front windscreen have been introduced from many metro stations. These CCTV and GPS enabled e-rickshaws operate within an area of 3-4 km around metro stations.

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**Electric-bicycle (e-bicycle) service:** The specially designed battery operated cycle service operating from select Metro stations is helpful in providing last mile connectivity to its commuters and to decongest the road traffic by propagating environment-friendly modes of transport over personal vehicles.

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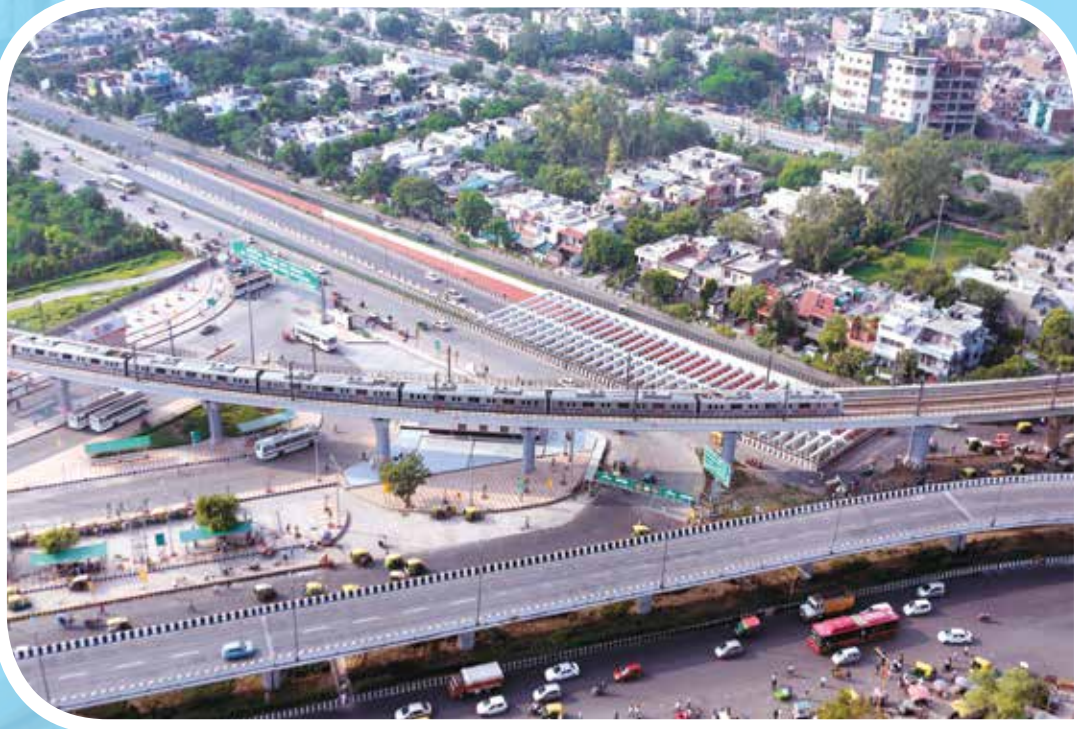
# ACRONYMS & ABBREVIATIONS



**Under Phase-III, Metro** has given a major infrastructure boost to Delhi-NCR public by expanding to around 160 km. Inter line connectivity through multiple interchange stations and extension of existing lines have eased the commuting experience for millions of passengers.

# ACRONYMS & ABBREVIATIONS

| | |
|---|---|
| ABS | Antilock Braking System |
| AD | Anno Domini |
| ANPRS | Automatic Number Plate Recognition System |
| APMS | Advance Parking Management System |
| APS | Automated Parking System |
| APTS | Advance Public Transport System |
| AQMC | Air Quality Monitoring Committee |
| ATC | Area Traffic Control |
| ATCS | Automated Traffic Control System |
| ATL | Average Trip Length |
| ATIS | Advance Traveller Information System |
| | |
| BAU | Business As Usual |
| BEST | Bombay Electric Supply & Transport Undertaking |
| BMRDA | Bombay Metropolitan Region Development Authority |
| BMTC | Bengaluru Metropolitan Transport Corporation |
| BRT | Bus Rapid Transit |
| BS | Bharat Stage |
| | |
| CAGR | Compounding Average Growth Rate |
| CBD | Central Business District |
| CCS | Central Control Station |
| CCTV | Close Circuit Tele Vision |
| CDM | Clean Development Mechanism |
| Climate FIT | Climate Finance Impact Tool |
| CNG | Compressed Natural Gas |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| CPCB | Central Pollution Control Board |
| CRRI | Central Road Research Institute |
| CVO | Commercial Vehicle Operation |
| | |
| DDA | Delhi Development Authority |
| DGCA | Directorate General of Civil Aviation |
| DLF | Real Estate Company in India |
| DMRC | Delhi Metro Rail Corporation |
| DPC | District Planning Committee |
| DTC | Delhi Transport Corporation |
| | |
| ECS | Equivalent Car Space |
| EIRR | Economic Internal Rate of Return |

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|---|---|
| EMI | Equal Monthly Instalment |
| ET | Economic Times News Paper |
| ETA | Expected Time of Arrival |
| ETC | Electronic Toll Collection |
| ETCS | Electronic Toll Collection System |
| EURO | European Stage (Standard) |
| EV | Electric Vehicle |
| FNAE | Fellow of Indian National Academy of Engineering |
| GDP | Gross Domestic Product |
| GF | Ground Floor |
| GHG | Green House Gas |
| GIS | Geographic Information System |
| GIZ | Gesellschaftfür Internationale Zusammenarbeit (German Development Agency) |
| GOI | Government of India |
| GPR | Ground Penetrating Radar |
| GPRS | General Packet Radio Service |
| GPS | Global Positioning System |
| GRAP | Graded Response Action Plan |
| GSM | Global System for Mobile |
| GVW | Gross Vehicle Weight |
| $HC_S$ | Hydro Carbons |
| ICCC | Integrated Command & Control Centre |
| ICT | Information and Communication Technology |
| IDFC | Infrastructure Development Finance Company |
| IIHS | Indian Institute of Human Settlements |
| IIT | Indian Institute of Technology |
| INC42 | Indian Media and Information Platform (for Indian Startup Ecosystem) |
| INR | Indian Rupees |
| IPEA | International Professional Engineers Agreement |
| IPIS | Integrated Parking Information System |
| IPT | Intermediate Public Transport |
| ITMS | Integrated Traffic Management System |
| IRC | Indian Roads Congress |
| IT | Information Technology |
| ITS | Intelligent Transport System |
| IUT | Institute of Urban Transport |
| IWT | Inland Water Transport |
| IVRS | Interactive Voice Response System |
| JICA | Japan International Cooperation Agency |
| JNNURM/JnNURM | Jawaharlal Nehru National Urban Renewal Mission |
| KPI | Key Performance Indicator |

| | |
|---|---|
| KPMG | International Professional Service Company |
| KSRTC | Karnataka State Road Transport Corporation |
| LED | Light Emitting Diode |
| LIDAR | Light Detection and Ranging (a remote sensing method) |
| LPG | Liquefied Petroleum Gas |
| LRT | Light Rapid Transit |
| LTA | Land Transport Authority, Singapore |
| MGI | McKinsey Global Institute |
| MIP | McKinsey Infrastructure Practice |
| MITRA | Mysore Intelligent Transportation (Intelligent Bus Tracker Android App for KSRTC) |
| MLCP | Multi-Level Car Parking |
| MMRDA | Mumbai Metropolitan Region Development Authority |
| MoHUA | Ministry of Housing and Urban Affairs |
| MoRTH | Ministry of Road Transport and Highways |
| MOUD/MoUD | Ministry of Urban Development |
| MPC | Metropolitan Planning Committee |
| MRT | Mass Rapid Transit |
| MRTS | Mass Rapid Transit System |
| MTC | Madras Transport Corporation |
| MTW | Motorised Two Wheeler |
| NCR | National Capital Region |
| NDMC | New Delhi Municipal Corporation |
| NGO | Non-Government Organisation |
| NGT | National Green Tribunal |
| NITI | National Institute for Transforming India |
| NIUA | National Institute of Urban Affairs |
| NMT | Non-Motorised Transport |
| $NO_X$ | Nitrogen Oxides |
| NPRS | Number Plate Recognition System |
| NTDPC | National Transport Development Policy Committee |
| NTPC | National Transport Policy Committee |
| NUTP | National Urban Transport Policy |
| OTS | Office of Transport Strategy |
| PBS | Public Bike Sharing |
| PIS | Passenger Information System |
| $PM_{2.5}$ | Particulate Matter, 2.5 Micron |
| $PM_{10}$ | Particulate Matter, 10 Micron |
| POS | Point of Sale |
| PPAC | Petroleum Planning & Analysis Cell |
| PPP | Public Private Partnership |
| PT | Public Transit |
| Pune MPML | Pune Mahanagar Parivahan Mahamandal Limited |

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|---|---|
| PV | Private Vehicle |
| PWD | Public Works Department |
| RFID | Radio Frequency Identification Device |
| RITES | Rail India Technical & Economic Services |
| RTO | Regional Transport Office |
| SDG | Sustainable Development Goal |
| $SO_2$ | Sulphur Dioxide |
| SMS | Short Message Service |
| SRTU | State Road Transport Undertaking |
| STC | State Transport Corporation, Calcutta |
| SUSTRANS | Sustainable Transportation System |
| TDM | Travel Demand management |
| TERI | The Energy Research Institute |
| TfL | Transport for London |
| TFS | TaxiForSure |
| TLRN | Transport for London Road Network |
| TOD | Transit Oriented Development |
| TRIPP | Transportation Research and Injury Prevention Programme |
| T&T | Traffic & Transportation |
| TV | Television |
| TW | Two-Wheeler |
| UK | United Kingdom |
| ULB | Urban Local Body |
| UMTA | Unified Metropolitan Transport Authority |
| UN | United Nations |
| US | United States |
| USD | United States Dollar |
| UT | Urban Transport |
| UTF | Urban Transport Fund |
| VHT | Vehicle Hours Travelled |
| VIP | Very Important Person |
| VKT | Vehicle-Kilometres Travelled |
| VMS | Variable Message Sign |
| VOC | Vehicle Operating Cost |
| VTMS | Vehicle Tracking & Monitoring System |
| VTPI | Victoria Transport Policy Institute |
| WB | The World Bank |
| WHO | World Health Organisation |
| WRI | World Resources Institute |
| WSA | Wilbur Smith Associates |

# ANNEXURE:
# REPORT ON THE BRAINSTORMING WORKSHOP

DMRC is meeting 35% of total energy needs from renewable sources like Roof-top solar plants, Off-site plant and Waste to Energy Plant. It has set up roof top solar power plants at many of its stations, depots and residential colonies. All stations of the Phase-III have been constructed as green buildings.

# ANNEXURE: REPORT ON THE BRAINSTORMING WORKSHOP

A Brainstorming Workshop was held on July 10, 2019 to discuss the Draft Report of the study, with as wide a representation as possible from amongst the stakeholders, in order to get their views/ suggestions, before finalising the same. A copy of the Executive Summary was made available to the participants prior to the workshop.

Dr. Mangu Singh, FNAE, MD DMRC, kindly provided the support base for organising the workshop, and, it was held at the Metro Bhawan New Delhi. Dr. V. K. Saraswat, FNAE, member Niti Aayog, kindly graced the inaugural session as the Chief Guest, and Dr. Sanak Mishra, President INAE spared his valuable time to preside over it. Also present was Dr. Pradip, Vice-President INAE. Dr. Prem Krishna, Chairman of the INAE Forum on Civil Infrastructure, made a presentation on the Background and Salient Aspects of the Report. The session was well attended.

There were two technical sessions at which features of the report were presented and discussed. In the first session, chaired by Prof. S. S. Chakraborty, FNAE, a presentation on Organisational and Policy Issues was made by Dr. Mangu Singh, and, Prof. Tandon, FNAE, presented his views on 'Infrastructure-Engineering Issues'. The post lunch technical session, was chaired by Mr. Rakesh Chopra, former Member Engineering of the Indian Railways. Presentations were made by Dr. Satish Chandra, Director, Central Road Research Institute (CRRI), on Multi-Modal Transport, and, by Dr. Sikdar, FNAE on ITS (Intelligent Transportation System). Both sessions had very meaningful discussions.

Valuable comments were made by the President INAE at the closing session.

The purpose of the Workshop was well served and the inputs received have helped to finalise the Report and take it forward.

A list of the participants, besides those mentioned above, is given below.

**List of Participants**

| | | | |
|---|---|---|---|
| 1 | Shri S. K. Nirmal | Secretary General | Indian Roads Congress (IRC) |
| 2 | Ms. Minal | Scientist | CSIR-CRRI |
| 3 | Mr. Ritwik Singhal | Deputy General Manager | NCRTC |
| 4 | Dr. Kamal Kant Jain | Assistant Professor | BML Munjal University |
| 5 | Prof. Sanjay Gupta | Head, Transport Planning Deptt. | SPA |
| 6 | Dr. Abhishek Jindal | Assistant Professor | BML Munjal University |
| 7 | Dr. S. Velmurugan | Senior Principal Scientist | CSIR-Central Road Research Institute (CRRI) |

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|---|---|---|---|
| 8 | Dr. Pankaj Kant | Ph.D Research Scholar, Transport Planning Deptt | SPA |
| 9 | Prof. M. Parida | Deputy Director | IIT Roorkee |
| 10 | Dr. Monika Singh | Ph.D Research Scholar, Transport Planning Deptt | SPA |
| 11 | Ms. Monika Agrawal | General Manager | Ayesa, Noida |
| 12 | Mr. Pankaj Gupta | | DDA |
| 13 | Dr. S Meena | | DDA |
| 14 | Dr. Shailendra Sharma | | DDA |
| 15 | Dr. Kushagru Sinha | | SPA |
| 16 | Mr. PK Garg | Executive Director, Technical | DMRC |
| 17 | Mr. AK Garg | Director, Ops | DMRC |
| 18 | Mr. Vivek Agarwal | | NBCC |
| 19 | Mr. RS Rao | General Manager, Projects | DMRC |
| 20 | Mr. AK Singh | Executive Director, Electrical | DMRC |
| 21 | Mr. Alok Bhowmick | Managing Director | BSEC (Bridge & Structural Engineering Consultants, Noida) |
| 22 | Mr. Pradeep Sharma | | Institute of Urban Transport (India) |
| 23 | Ms.Sania Arora | | Institute of Urban Transport (India) |


**Inaugural Session in Progress**

**Dr. Prem Krishna Speaking on the Background and Salient Aspects of the Report**

**Dr. V. K. Saraswat, the Chief Guest, Inaugurating the Workshop.**


**Dr. Mangu Singh, MD, DMRC, Presenting a Memento to Dr. Saraswat**

## The Study at a Glance

The INAE document on VISION, MISSION & VALUES, 2037, brings out the fact that, areas such as Engineering Education, Energy, Infrastructure (with its various aspects), take center stage, and will continue to do so for National development. The subject area of INFRASTRUCTURE would deem to include Traffic & Transportation; Housing; different aspects of Water; Energy; and, so on.

The INAE set up a new forum on CIVIL INFRASTRUCTURE in January 2018 to study the areas of Traffic & Transportation, Housing, and, Water. To begin with, the Forum has addressed the issue of Traffic & Transportation.

It emerged from the initial deliberations that the woes related to intra-city Traffic and Transportation are not just due to any one or two issues, but have many dimensions – managerial, technical, societal, educational, and so on. Thus, it became obvious that if our Cities have to become more comfortable to live in, a holistic approach will have to be followed considering all aspects of Traffic and Transportation. Out-of-the-box thinking and some hard decisions would seem imperative. It is only then that an efficient, sustainable, and, safe system will emerge for Traffic and Transportation. Fortunately, today e-technology can provide much valuable support in achieving the above.