

JUNE 2017

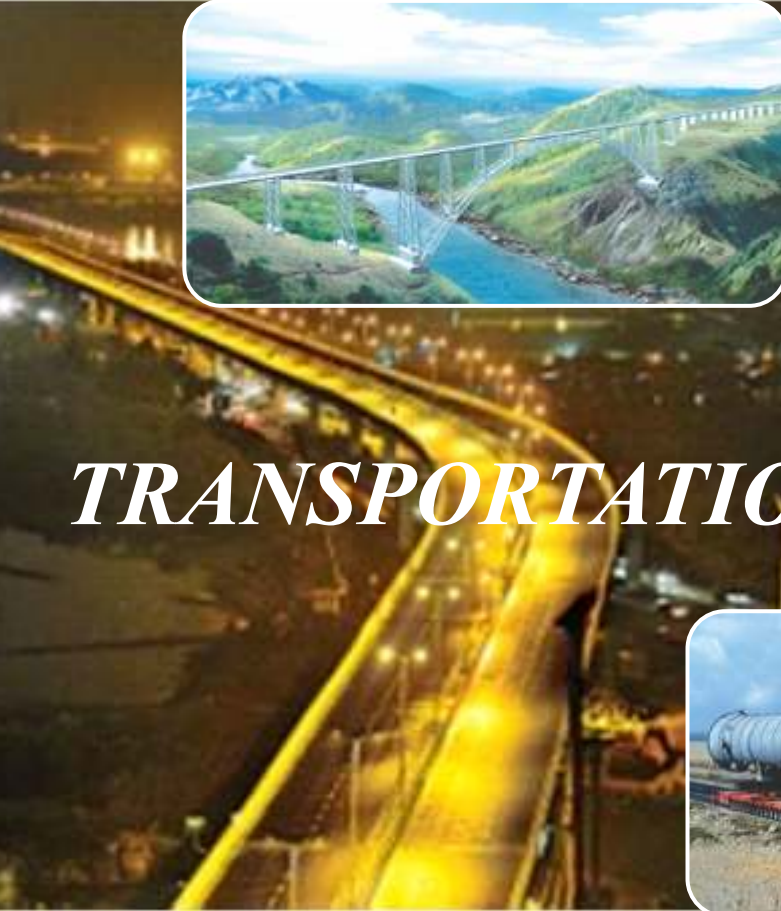
VIEWPOINT

OFFICIAL QUARTERLY MAGAZINE OF CEAI

www.ceai.org.in



TRANSPORTATION

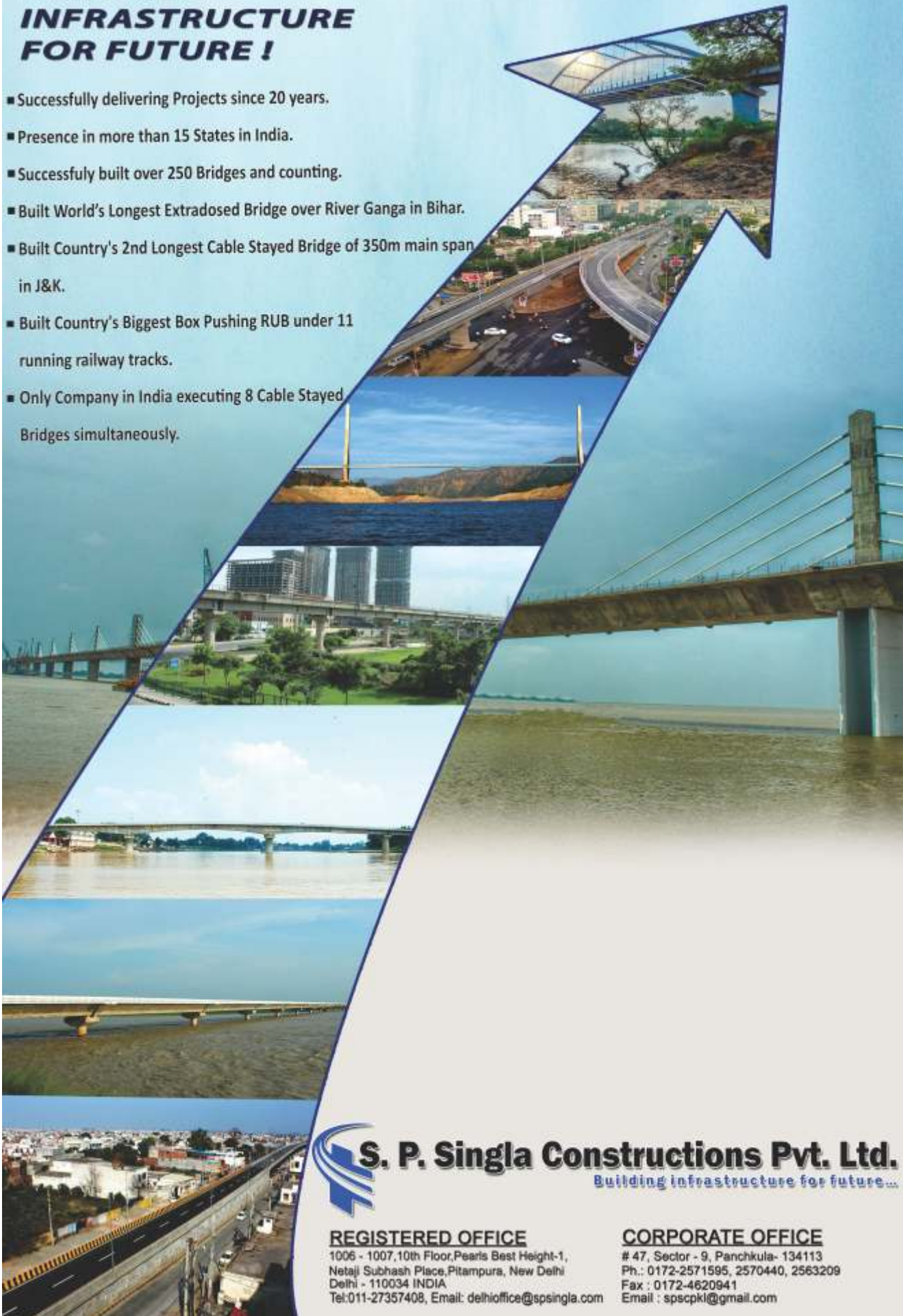


**CONSULTING ENGINEERS
ASSOCIATION OF INDIA**

Creating Value for Engineers

BUILDING INFRASTRUCTURE FOR FUTURE !

- Successfully delivering Projects since 20 years.
- Presence in more than 15 States in India.
- Successfully built over 250 Bridges and counting.
- Built World's Longest Extradosed Bridge over River Ganga in Bihar.
- Built Country's 2nd Longest Cable Stayed Bridge of 350m main span in J&K.
- Built Country's Biggest Box Pushing RUB under 11 running railway tracks.
- Only Company in India executing 8 Cable Stayed Bridges simultaneously.



S. P. Singla Constructions Pvt. Ltd.

Building infrastructure for future...

REGISTERED OFFICE

1006 - 1007, 10th Floor, Pearls Best Height-1,
Netaji Subhash Place, Pitampura, New Delhi
Delhi - 110034 INDIA
Tel: 011-27357408, Email: delhioffice@spsingla.com

CORPORATE OFFICE

47, Sector - 9, Panchkula- 134113
Ph.: 0172-2571595, 2570440, 2563209
Fax : 0172-4620941
Email : spscpk@gmail.com

JUNE 2017

VIEWPOINT

OFFICIAL QUARTERLY MAGAZINE OF CEAI

www.ceai.org.in

CONTENTS

1	Message From Chief Editor
3	Message From Editor - Transportation
5	The Future of Transportation - Are We Professionals Prepared? - <i>Amitabha Ghoshal</i>
12	Strategy Framework for Intelligent Transport System in Multi-Modal Transit Hub - <i>Abhishek Haldar & Dr. Ritesh Tiwari</i>
20	Rapid Urbanisation in India: Development in Transportation Sector - <i>Dr. B C Roy and S Bhattacharyya</i>
29	Planning of Lohia Path Chakra Project in Patna, India - <i>Fani Bhushan</i>
43	Future shapes of bridges in urban environment - <i>Max MEYER, Dr. sc. h.c. ETH,</i>
47	Civil Engineering Innovation Shaping Mobility of the Future - <i>Dr. Boris Reyher and Prof. Dr. Mike Schlaich</i>
51	Unique Engineering Features of Delhi Metro - <i>Dr. Mangu Singh</i>
56	Past Practice & Recent Developments in Seismic Design of Transportation Structures (Bridges) as Per Indian Standards - <i>Alok Bhowmick</i>
71	Proposed Alternative Mechanisms to Award Works Contracts - <i>K K Kapila</i>
77	Brief Proceedings of the Third Asia - Pacific Conclave on Dry Extraction and Effective Utilization of Bottom Ash & Technological Advances in other Coal Combustion Products and Emissions in Thermal Power Plants
81	CEAI News
90	FIDIC News
92	Other News, Views, Notes
94	Tech Quiz

EDITORS BOARD

Chief Editor

Mr A P Mull, Chief Editor

Mr Alok Bhowmick, Editor - Transportation

Members

Mr Sudhir Dhawan

Mr Somenath Ghosh

Mr R Khazanchi

Mr Pradeep Chaturvedi

Dr S Chatterjee

Mr Alok Bhowmick

Mr R Gogia

Complete Solution For The Construction Industry



All you need in civil engineering applications

- Integral Water Proofing Compounds
- Surface Applied Water Proofing Coatings
- Tile Fixing Adhesives And Joint Fillers
- Structural Repair Products
- Stone, Granite & Marble Enhancer
- Bonding Agents
- Plasticisers
- Flooring Products
- Industrial Coatings

AN ISO 9001 : 2008 & NSIC - CRISIL SME - 1 RATED COMPANY



PERMA CONSTRUCTION AIDS PVT. LTD.

611 / 612, Nirmal Corporate Centre, Mulund (W) Mumbai - 400 080, India.

Tel.: 91-22-2591 8911 / 2567 4690 • Fax : 2590 3008

E-mail: info@permaindia.com • Visit us at www.permaindia.com





MESSAGE FROM CHIEF EDITOR

Dear Fellow Consulting Engineers,

Urbanisation has brought in its wake many benefits for the upliftment of the quality of life but has also presented us with many challenges especially due to unplanned development which needed to be solved.

Earlier the lifespan of humans was short but with increased awareness and improved healthcare facilities the mix of population to be catered to has also changed. The productive life of people has gone up since they are living healthier lives longer. On the other hand India's demographic dividend has placed many young people into the work force. As per The World Bank India's work force was 328.576 million in 1990 and increased to 511.066 in 2016 against the World's figures of 2.343 billion and 3.422 billion respectively. Thus more and more people are commuting and a greater number are independently mobile. They all look for and expect enhanced ease and speed of travel in a safe manner.

Till some years ago it was really only in Mumbai that alternative means of transport were available at all times. Mumbai has the Suburban Railways as its lifeline and they provide a living example of how well mass transportation can be addressed. The roads surely cannot cope with the demand.

All urban areas must allow only planned development and provide wide tracts of land for future transportation needs. There needs to be holistic planning for all the underground services so that no digging is ever required. The services would inter alia include water, wastewater, stormwater, electricity and communication. Electric battery powered vehicles and Hydrogen Cell powered vehicles are being brought out for public usage and these would require charging stations. Their requirements would also need to be built in to Future Proof the 100 Smart Cities that are being developed. We trust that these aspects are taken care of so that they benefit from the experience of the existing urban areas.

Autonomous vehicles are being talked of, so let us just ponder on as to what infrastructure they would require. Since they will run on sensors what first needs to be ensured is that right across the country only one system of specifications and standards are adhered to and works done to those so that the autonomous vehicles don't encounter for instance different road/ lane widths, curves or kerb heights or signal systems. A constantly changing parameter could put a spanner in their sensing and computing systems. Continuous surveillance is another aspect which would need to be factored in to safely bring to halt any autonomous vehicle that may develop a fault.

The advances in digitisation must be judiciously incorporated so that the people are kept aware of the functioning of the urban area, especially its transport systems

MESSAGE

around the clock. The various transport systems, be it land, water or air systems, must be all integrated to provide end to end facilities to the inhabitants.

To achieve the above what is required is that the project authorities, the planners, the designers and the constructors all work in unison. The decisions would need to be taken on the basis of the technical requirements and not any other extraneous consideration. Only then can India build world class transport systems.

As Engineers, it becomes our duty to advise the correct technical method, process or procedure to be adopted. It would all start with first defining the Design Life of the facility. We have examples of works done a 100 years ago which are standing and still being fit for the purpose intended. For infrastructure works which all require large funding and time to build, it is necessary that 100 years be their Design Life so that they do not present problems for the immediate next generation. This is necessary for Green Engineering and Sustainable Development.

Happy Reading and Learning



A P Mull



MESSAGE FROM EDITOR -TRANSPORTATION

It is a matter of pride for members of the Consulting Engineers Association of India (CEAI) to read the quarterly journal of the association, VIEWPOINT in its new avatar, with effect from March 2017, when the journal has started publication on a theme based issue. The March 2017 issue was on the theme of 'Water & Sustainability' and the current issue is on 'Transportation'.

The *Transportation* theme was considered as most appropriate considering India's large scale investment in Infrastructure for rapid economic growth and the diverse nature of India's transport sector, which caters to the needs of more than 1.34 billion people.

The predominant trends influencing mobility of the population in Indian cities are rapid urbanisation, rising motorisation and dwindling modal share of Non-Motorised Transport (NMT). These factors have resulted in a sudden rise in the demand for travel. At the same time, the rapidly increasing levels of motor vehicle ownership and use has resulted in an alarming increase of negative externalities such as road congestion, air pollution, road fatalities, and social issues of equity and security.

It is hoped that the content of this journal will inspire the planners, designers and executioners to come out with more aesthetic, more sustainable and cost effective transportation structures and systems in the near future. Although the papers/articles selected in this issue constitute only the tip of an iceberg, they are still a representative sample of the issues that concerns the society on transportation. The current issue comprises of 9 theme based papers which we consider should be of interest to our readers.

The first paper '*The Future of Transportation – Are We Prepared*' by Mr Amitabha Ghoshal gives us a glimpse of what is in store for the future generation in road transportation, aviation industry as well as the railway sector. Electric Vehicles, Automated Vehicles, High speed trains, Personal Airborne Transportation Systems (PATs) are some of the features highlighted in the paper.

Mr Abhishek Halder & Mr Ritesh Tiwari in their paper titled '*Strategy Framework for Intelligent Transport System in Multi-Modal Transit Hub*' have very appropriately pointed out the benefits of ITS and the vision for ITS in multi-modal transport hub. The paper highlights various initiatives taken by GoI in this regard, the challenges ahead and the key drivers for growth in this sector.

Dr B C Roy and Mr S Bhattacharyya in their paper titled '*Rapid Urbanisation in India: Development in Transportation Sector*' gives a snapshot of the state of practice in transportation sector in India and have highlighted the urgent need for appropriate public transport system with proper integration amongst different modal transport.

Mr Fani Bhushan in his paper on '*Planning of an Urban Grade Separator - Lohia Path Chakra*', highlighted the unique features of the under-construction project at Patna, Bihar, with new generation of traffic interchanges. The solution proposed in this grade separator has several new and innovative concepts of traffic planning as well as structural engineering, which have never been tried before in India.

Mr. Max Meyer in his paper '*Future Shapes of Bridges in Urban Environment*' has highlighted various challenges the designers face for design of Bridges in urban environment. The defining factors are stated to be a) Impact on city's architecture, b) impact on city dwellers during construction, and c) carbon footprint during construction and operation. He has highlighted the necessity to provide for physical mobility though virtual mobility, which is gaining more and more importance.

Dr Boris & Prof M Schlaich in their paper '*Civil Engineering Innovation Shaping Mobility of the Future*' have talked of several exciting reference bridge projects demonstrating the Civil Engineering innovations and all those bridges are very elegant. They have demonstrated the use of integral bridge concepts in many examples. They have also highlighted the need for Civil Engineers to use creativity and innovation in every design and have focused on the need for a holistic approach in design of Transportation structures.

Dr Mangu Singh in his presentation '*Unique Engineering Features of Delhi Metro*' has highlighted the Salient Engineering Features of Delhi Metro plans since its formation in 1997. He has discussed the challenges in planning and execution, principles adopted in selecting technology for underground tunnels, underground stations, viaducts as well as over ground stations of Delhi Metro.

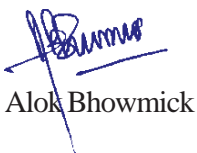
Mr. Alok Bhowmick's paper titled '*Past Practice & Recent Developments in Seismic Design of Transportation Structures (Bridges) as Per Indian Standards*' traces back the history of evolution of the seismic design standards in India by various code making agencies and takes stock of the current seismic design standards in the country for highway and railway bridges.

It is hoped that the selected theme papers in this special issue of the journal on '*Transportation*' will give an insight into the subject, provide a reference point for planning and design of transportation projects in future and help us to review the current practices, reflect on its deficiencies and give fresh ideas for course correction for future developments.

In addition to the theme papers, this issue of View Point also has published a paper by Mr. K K Kapila on an important topic which affects all sectors of construction. In his paper titled "*Proposed Alternative Mechanisms to Award Works Contracts*" he has shared the work carried out by task force led by Mr. Kapila, for FIDIC. The objective of this study was to identify alternative best practice contractor selection methodologies that can be applied world-wide, depending on the complexity of the project and the procurement and technical sophistication and capacity of the procuring entity.

Last but not the least, Mr. Mainak Ghosal has reported on the proceedings of the 3rd Asia Pacific conclave on "*Dry Extraction and Effective Utilisation of Bottom Ash and Technological Advances in other Coal Combustion Products and Emissions in Thermal Power Plants*"

I wish all the readers a Happy Reading!



Alok Bhowmick

The Future of Transportation - Are We Professionals Prepared?



Amitabha Ghoshal
STUP Consultants Pvt. Ltd

Abstract: *Transportation sector is going through radical changes across the world and innovations in all the sectors have moved beyond the design stage, with prototypes undergoing trial.*

Disruptive global mobility solutions, with the aim to provide better solutions and ensure safe, efficient, sustainable transportation to the people by 2030 are on trial.

In case of road transport, Electrical Vehicles (EV) are already on road in India and making newer demands on Infrastructure. The logical next step, Automated Vehicles (AV), earlier ridiculed as TESLA's folly, is on Road trials in US, Singapore and Nordic countries of Europe, and expected to replace ten percent of conventional vehicles in US by 2025. EV and AV will make profound changes on Road infrastructure. Manufacturing initiative will shift from Ford and Toyota to Intel and Google and with 3D printed cars the O&M scenario will change forever.



Electrical Vehicles (EV) charging station

In Aviation sector, Personal Airborne Transportation Systems (PATS) will take forward the impact, created by Drones already across the globe, to new dimensions.

With introduction of Electricity driven commercial vehicles, Railway sector will loose out in competition with Road transportation. The effort therefore is on to replace the Railway network with high speed, high density autonomous network that will seamlessly interface with the existing Road infrastructure.

The environmental disaster that looms today, due to emissions from Internal Combustion engines will recede substantially and new norms of safety and environmental engineering will have to be in place.

The Brave New World, that is due to emerge, will change demands on Engineering Infrastructure and Consultants will have to plan ahead, along with politicians and planners.

Should the Indian Consultancy Industry get prepared for the future, or is it too early - that question is attempted to be answered in this paper.

INTRODUCTION

Our world is going through a second technological revolution, aided by Digital Technology, Artificial Intelligence and 3D Printing, changing forever all the facets of human living. The Sci-FI imageries are becoming real life experience, much faster than we have been planning for our future demands. The transportation sector is no exception.

It is essential that all long term planning takes into account the needs of the society that will emerge with the changes that technology will impose, perhaps sooner than later. Investments planned for long term infrastructure development must take into account the ongoing developments in technology and build in features for the transition period from present usage to the ultimate shape of infrastructure requirement.

For developing countries like India, with limited resources, this future study is essential, lest our developed infrastructure becomes inadequate or redundant within their planned service period.

CHANGES THAT ARE LOOMING
ROAD TRANSPORTATION – the Automated Vehicles (AV)

We have been accustomed to the use of IC Engines for Road Transport and have been admiring at the rapid improvements in technology in design of such vehicles, bringing in higher speeds, larger carrying capacity and at the same time lower emission norms. Our planning centers on continued use of such vehicles.

Electrically driven vehicles are already being marketed in India, demanding new infrastructure facilities like charging stations that are being hurriedly built besides traditional fueling stations.

The next logical development is Automated Vehicles (AV), which is already a reality in many countries. What was once scoffed as TESLA’s folly is today dominating headlines in our country as well.

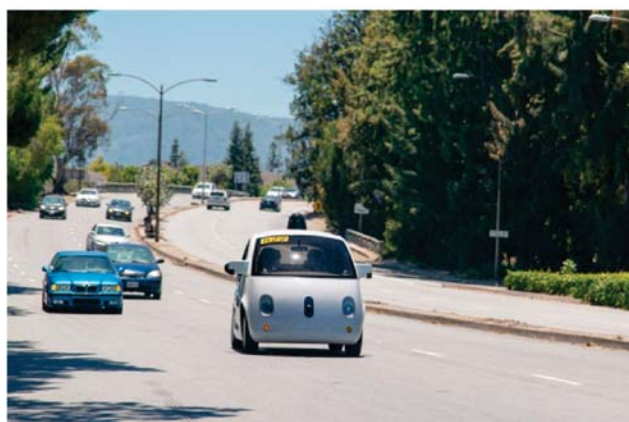
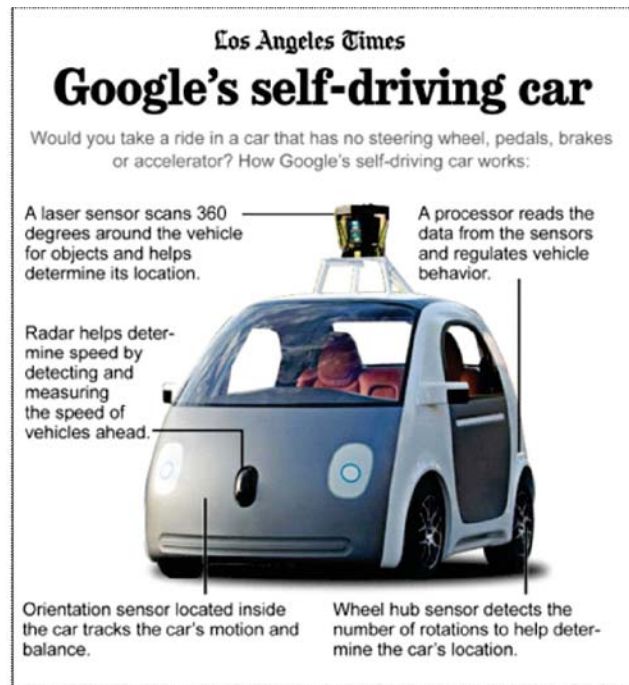
This is best reflected in three news headings in Economic Times coming up on a single date (17-04-2017) and they were:

- ❖ “Apple to test self-driving cars after Nod”
- ❖ “On the Road: Tesla will unveil two Electric Trucks in September”
- ❖ “GM to add 1000 jobs to Self-Driving programme”

Canada has deployed one third of the large trucks that operate in the oil sand fields in the province of Alberta as AV and are curtailing man power.

Six US states- California, Florida, Michigan, Nevada, North Dakota and Tennessee have legalized AV trials on in service roads and 20 more states are looking at AV legislation.

Volvo has undertaken to run a 100 car AV project in its headquarters city of Gothenburg. Australia, China, France, Japan, Korea, Netherlands and Singapore are having serious government supported AV initiatives.



Automated vehicle plying with other cars

All the above merit serious introspection by transport planners in our country, as AV deployment may overtake the infrastructure preparedness. AVs are not just on some drawing board somewhere, but are already in operation in some parts of the world. Being a transformative technology, AVs will soon impact the average person- initially in the developed world, but in countries like ours also, in not too distant a future. It is worth noting that, while it took 12 years for the car population in New York to go up from 4192 (1900) to 356,000 (1912), cars had made their debut in colonized India in between this period. Today's technology driven Indian nation is likely to develop things faster. We should bear in mind that MORTH and NITI AAYOG are seriously examining the possibility of installing HYPERLOOP, a technology that has not been yet tried out in any country, and going to cost considerably more for developing its infrastructure!

AVs are being designed to use existing road infrastructure and that may generate greater challenges during the transition period. AVs are able to travel close to each other, as close as 5 cm, both longitudinally and transversely with the help of sensors, and do not need traffic lights or lane dividers. Negotiating driven cars, which will still be on the road, are one of the major nightmares for the designers. The problems will be eventually overcome, through ever more powerful computers, by 3D laser scanning and by GPS positioning technology. The key first success will be to ensure that AVs can negotiate the built environment of the standard Indian urban complex.

Use of AVs has many benefits- the most important one for us is Safety! By removing the human driver, one not only adds to passenger capacity, but eliminates 95% of the accidents, that occur due to human error. The run up to Vision Zero, creation of a zero fatality transport environment, has begun.

AVs will be travelling closely- so on highway the cargo vehicles will travel as a train, nearly bumper to bumper. This will increase the capacity of existing carriageways measured in terms of vehicles per hour. It may be necessary to divide the carriageway into AV and Non-AV lanes. It is very likely that initially our six lane / eight lane corridors will be found to be too wide

The big challenge will be for Bridge designers, in ensuring that the Bridges do not collapse under large vehicle concentration, much more in number than the present design recommendation.

Another societal change will be to transform the vehicular world into 'transport as a service' model-use of vehicles on short term rental basis in place of ownership basis. Trends in this direction are already evident with use of OLA/ Uber. Existing car-rental, car-share and taxi business may all converge to reduce the number of vehicles on the road. The efficiency of travel will increase, with time for parking and garaging eliminated. A beneficial side effect of this transformation will be the decline in need for Parking lots, releasing land for alternative use! The vehicle ownership model may change altogether and number of vehicles in use may decline.

There will be economical benefit with reduction in household expenditure for transportation, and, for the nation, from avoidance of accidents and congestion related cost, which amount to considerable percentage of GDP.

Use of AV will help solve two major national level issues our country faces:

- (i) There will be reduction in need for POL, an item India imports by using more foreign exchange than it earns from export of commodities. Serious efforts of the government in expanding solar power use rapidly will help in running the EVs and AVs.
- (ii) Reduction in the emission of obnoxious gases like NO, CO and CO₂ and particulates (large size), that IC engines discharge, and are a major health hazard for our population.

AVIATION SECTOR – The skies are set to change

The city of San Paulo in Brazil, one of the over grown Mega Cities of the world, has created a traffic nightmare, where a drive into the city takes two and half hours, and spawned an inter-city Air Taxi system. Currently 500 helicopters fly executives to helipads on downtown office buildings and take them back at the end of the day on routine basis. Urban Aeronautics Ltd of Israel is ready to launch its Intra-City Air-Taxi system after two decades of development and trial of their unmanned ‘Coromant Fancraft’. They are already planning for wider scale mass transport, depending on VTOL (Vertical Take-Off and Landing) aircraft, having large seating capacity, but needing limited foot prints. The system obviates needs for elaborate Helipads requiring large land coverage, enabling larger passenger transfer capacity per hour, compared to present day helicopter services. With advances in batteries and electric motors, the advent of electric VTOL is coming nearer, raising the prospect of reducing the cost per trip.



VTOL Air Taxi of UBER in UK

For Short distance city trips, PATS (Personal Airborne Transportation System) are becoming feasible with convergence of power communications and control technologies, and the breakthrough, in capability and cost, is creating a new industry. The Consumer Drones, that are becoming familiar everyday, with delivery of small cargo parcels and for aerial photography, are now aiming to invade the civilian space. Study is now on, to find solutions for integration into urban environments, and first/ last mile logistics. They will have to rely on warehouses, charging stations, drone zoning and drone parking facilities to be created.



PATS flying with passengers

In the coming years, the existing traffic situation in Megacities will deteriorate and the number of Megacities will increase, fueling faster development and deployment of these new modes of air transport.

We are all aware of the ongoing developments for long-flying aircrafts, with the emphasis on ever-larger carrying capacity with enhanced passenger facilities, and on reducing fuel consumption and reduction of noise level, from environmental concern. Correspondingly, less emphasis is on improving the infrastructure, to make them compatible with the new fleets of aircrafts. This is worsening the airport congestion.

Planners are resting their hopes on the developments taking place in US, of a ‘hybrid’ airship under Lockheed Martin, a defense industry player. The machines will have the potential to transport heavy payload over very large distances, without stoppage, and will not require runways or help of navigation towers. The airships, capable of carrying 20 ton materials and a dozen of workers over a distance of 2400 km at a moderate speed of 120 km/hr, are understood to be ready for supply, and they can take off with the full load from an unpaved clear space. Such equipment can change the viability and economics of far away construction sites, having limited connectivity.

All of the above will change the profile of Aviation Industry for the future

RAILWAYS – The challenge for the longest standing mobility format

Across the world the population is growing and Railway networks are experiencing unprecedented levels of demands for passenger transit. As a result, trains are overcrowded and platforms congested. The industry is in desperate need of extra capacity on the stressed infrastructure.

Interim solutions are being provided by a move towards Digital Railway, by improving signaling system to support automatic train operation and timetable management. The trains, train control and signaling systems are being vertically integrated to increase safety, reliability and capacity.

However, for intercity travel, High Speed rail is being viewed as the desired solution. A two track high speed line can carry more passengers than two new access controlled road links. With the technological developments, emerging from sustained research, high speed rail offers frequency, dependability and safety with a very low carbon footprint. This development will also release existing railway corridors and roads, to provide new capacity for passenger travel and cargo movement.



High Speed Trains of Shinkansen Technology in Japan

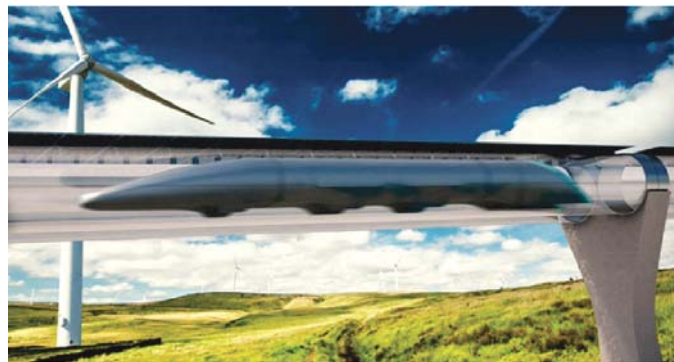
The High Speed 2 (HS 2) development project for connecting London to Birmingham is a pilot project in this direction and its performance is being closely watched by the Engineering community worldwide.

Closer home, Mumbai-Ahmadabad high speed line, using Japanese Shinkansen technology, is a move in the same direction. Studies are already underway for more high speed lines in the country.

The efforts today are to have trains that will have improved aerodynamics, and with help from aerospace engineers, create vehicles that will hardly touch the tracks, and that, with competitive costs. Light weight trains, with fibre glass body, are being developed to achieve this objective.

Rail faces a big challenge, in competing with the new forms of transport like the AV, in achieving travel at high speed, low cost but high levels of safety. The future game- changer is going to be the development of HYPERLOOP, a totally different imaginative technology, conceptualized by Elan Musk of TESLA, but now picked up by others.

Hyper loops are the first new mode of transportation in more than 100 years. This technology intends to move cargo and passengers faster than airlines through a low pressure tube by using electric propulsion and levitation, with very low energy consumption. HYPERLOOP travels through the tube, starting off on wheels and floating on magnets thereafter. It is fast, low cost, environment friendly and safe (no human errors).



Hyper loops model

Aiming to take one, from Kolkata to Patna distance in less than half an hour, the promoting company

has already started work on a test track and plans to start commercial operation in near future. With departures once a minute, and direct-to-destination service, HYPERLOOP is going to be a truly disruptive technology for travel inside a Metro city and for intercity travels as well.

WHERE LIES THE FUTURE

New transport systems are being developed and tested across the world. Large scale field operational tests are providing an insight into the potential impact on the user community. The new generation of automated transport systems requires to be tested for impacts beyond safety, mobility and fuel efficiency.

Disruptive technologies bring in unthought-of disruptions as well. Even after field trial with prototypes, new operational problems will come up requiring out-of-the-box technological solutions.

Some of the problems will remain unsolved, deflecting or discarding the innovation altogether, and fostering new innovations. There will be a disturbed gestation period that will have to be factored in the planning.

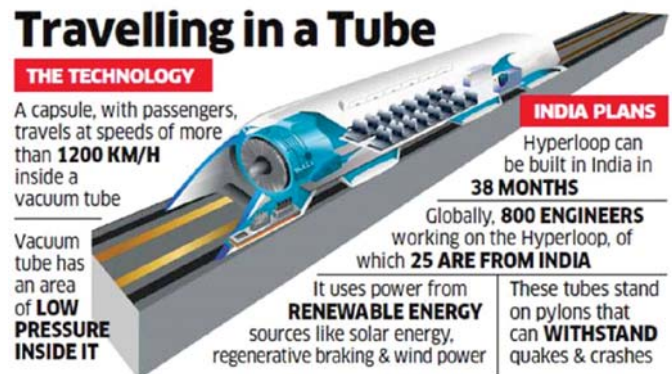
Not all of the Changes may prove to be acceptable to the society immediately – many legal and technical issues will have to be solved before successful investigation of the new transport units – many of the systems may prove to be beyond practical application. However, it is clear that, transportation modes are set for a quantum change.

Transport infrastructure is facing a host of issues: capacity constraints, population growth and climate change- all of these are putting pressure on the transport planners across the world. The frequently posed questions are – Can we create cities free from Traffic jams, - Should cars be banned from City Centers, – What radical changes can we ensure that cities of the future avoid total gridlock.

The symbiosis between mass transit and dense urban development is facing an onset of potentially disruptive transportation technologies as the growth of low-cost-on-demand autonomous transit becomes a reality over the coming years. Changes in road usage, car parking demand and requirement, goods delivery and waste collection strategies require that we rethink how to ensure the relationship between people and transportation from a sustainability and urban design perspective. From autonomous taxis to integrated bicycle networks, we are in the midst of first- and last-mile transit innovations that are yet transformative in impact.

High capacity transport systems need dedicated tracks in order to achieve desired capacity, reduce travel times and assure safety. On the whole, as cities grow, the only place available where new infrastructure can be put in to service the existing built environment of a city is underground. A system based on tunnels for electrically driven autonomous cars, where digital control ensures there is no congestion and no accidents, appears to be the solution. South Korean cities have started moving in this direction.

Roads take up a huge amount of space and the thinking should be how to take the mass transportation underground, leaving the surface for the people.



THE INDIAN SCENARIO

The world is moving away into the realms of Science Fiction, and achieving robust feasible solutions. If we think these innovations are day-dreams and not going to be achieved, we should recall that Internet became a reality only Twenty years back and we lived in a world free of mobile phones only Twelve years back.

While NITI AAYOG is seriously considering viability of HYPER-LOOP, and the PM declared moving on to Bullet trains as one of the priority development, the Engineering community is yet to grasp the changes that are going to come, and prepare for the challenges.

Today, across the developed world, and that includes China, serious discussions are on to figure out the future scenario in engineering developments. In Europe and USA, we find announcements of large conferences dedicated exclusively to the Future Developments in specific sectors. Our academics are yet to devote quality time to assess the future and direct research in this direction.

The Disruptive Technologies will demand radical changes in codal provisions and Design Specifications. Responsible bodies like BIS, RDSO, IRC and DGCA need be alert and plan for the oncoming changes and their ramification on present practices.

Learned societies like IEI or CEAI are keeping themselves involved with the present and encouraging discussions on ongoing issues only. While, in absence of any local research and industry inputs, it is difficult to have meaningful dialogue, should we not start awareness of the disruptive technologies that are nearing implementation, for the benefit of our younger generation.

Let us commence the dialogue and arm ourselves for the future, lest the future devours us intellectually.

Tata Motors-ISRO's Starbus fuel cell bus showcased in India

Tata Motors announced a concept model of its hydrogen-powered Starbus Fuel cell bus, it has developed in partnership with Indian Space Research Organisation (ISRO) in January this year. The vehicle has been designed for public transportation as its only emission is water vapour. The company had unveiled the technology at an auto expo in 2012, in which hydrogen combines with oxygen to power the electric motor and gives out water and heat as a by-product. The technology is also said to be environmentally safe with 'zero-emission'.

Company officials said the vehicle is about 50% more efficient than the conventional fuel-run vehicles, does not require external charging and has a driving range of up to 200 km. The fuel cell bus has been built on low entry platform with a ramp facility, pneumatic door operations among features.

Strategy Framework for Intelligent Transport System in Multi-Modal Transit Hub



Abhishek Haldar
Senior Engineer, TCE Limited,
Delhi NCR, India



Dr. Ritesh Tiwari
General Manager, TCE Limited,
Delhi NCR, India

Abstract: With rapid urbanization and introduction of new technologies in urban transportation systems, city commuters nowadays have multiple options of public transport modes to reach their destinations. However, due to lack of an unified urban transport master plan, all these public transport modes act as standalone systems. As a result, the government owned transportation systems give way to competition amongst themselves which leads to various efficiency and financial issues to the public agency as well as fail to effectively handle the transportation needs of the end city commuter.

To mitigate these issues, the public transportation systems need to be integrated so that they work together to meet the travel needs of the user. Multi-modal transit hubs are one of the key aspects to integrating public transportation systems. An Intelligent Transport System (ITS) forms a key component of the Multi Modal Transit Hub. It improves the overall experience of the passengers by providing timely information of their journey. For ITS to function effectively, various responsibilities/ functions needs to be clearly defined.

Keywords: Intelligent Transport System (ITS), Multi-Modal Transit Hub (MMTH), Light Rail Transit (LRT), Bus Rapid Transit (BRT), Public Transportation Systems, Passenger Information System (PIS)

1. Introduction

The Multi-Modal Transit Hub (MMTH) is a combination of a transportation facility integrating diverse local and inter-regional travel modes of which an Intelligent Transport System (ITS) is a key component. The goal of the MMTH is to provide efficient and reliable service to their riders. For that, the information about the service of buses and rail must be efficiently and effectively made available to the public. This would be achieved by implementing a Passenger Information System (PIS) which would be part of a broader ITS network for MMTH. A simple framework of technology for MMTH is shown in Fig. 1.

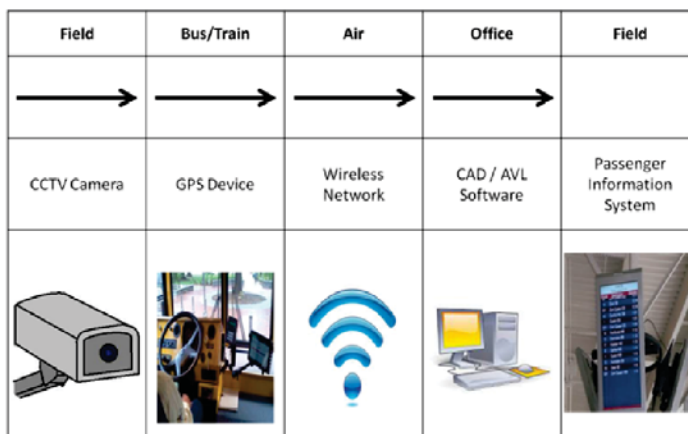


Fig. 1: Technological framework of ITS for MMTH

2. Benefits of ITS

One of the key features of the ITS is to improve the overall experience of the passengers by providing timely real time information of their journey. The ITS is envisioned to provide the following features as showed in Fig. 2.

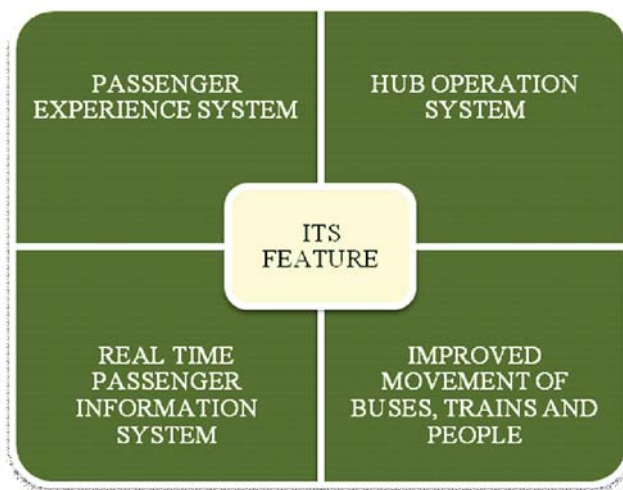


Fig. 2: ITS features at MMTH

The benefits associated after implementation of ITS for MMTH are as under:

- Real Time Information and Notification to Passengers
- Live Information of Bus/Train/BRT/MRT Arrival, Departures and Routes
- Increased Dispatch Efficiency of Vehicle and People
- Dedicated Hub operations for 24 hour monitoring of MMTH
- Escalator and stair provisions for movement of people
- Actively monitor movement of buses through the hub and vicinity
- Reduced Waiting Time
- GPS linked Bus Fleet Management System
- Provision of live bus operations data
- Variable Message Sign Boards

3. ITS Vision for MMTH

Some of the critical ITS elements that are needed to provide benefits to various stakeholders including the public at large are:

- Travel and Traffic Management
- Commercial Vehicle Operations
- Emergency Management
- Maintenance and Construction Management
- Public Transportation Operations
- Advance Vehicle Control and Safety Systems
- Information Management
- Electronic Payment

To achieve the vision of ITS for MMTH, the system would need to have the components listed below to ensure safe, efficient, reliable and comfortable movement of people and vehicles within the transit hub:

- Vehicle tracking facility for buses/ trains
- Passenger Information systems inside buses/ trains
- Real Time Passenger Information System in the MMTH
- Live Bus operations data to bus operators and regulators
- 24 Hours Monitoring of station and bus terminals
- Integrated Bus fleet management system

- Bus/Train/BRT/LRT passenger information
- Integrated Security and Monitoring by efficient CCTVs, Passenger Screening, Explosive Detection and allied systems for operational efficiency and improved safety and security
- Dedicated Mobile App to provide real time bus and train information
- Data Center facility
- Vehicle mounted GPS units
- Direct feed from Railways Information System
- Central Monitoring Station and Operation Centers (Command and Control)
- Divisional Monitoring and Operation Centers
- A dedicated Call Center
- Administration facilities

The implementation of ITS and modernization of the various existing facilities of the stand alone public transportation systems would require involvement of multiplicity of organizations and stakeholders. It is envisioned that various elements of ITS should be implemented with thrust on providing real time information to passengers as well as for secure and smooth movement of people interchanging at the MMTH.

ITS planning helps in shaping a well balanced transportation system that can meet future demands. As planning is normally made for long period, installing ITS facilities needs to be updated and one should ensure that the equipment and technologies are compatible for future improvement and expansion. A simple architecture of ITS for MMTH is shown in Fig. 3.

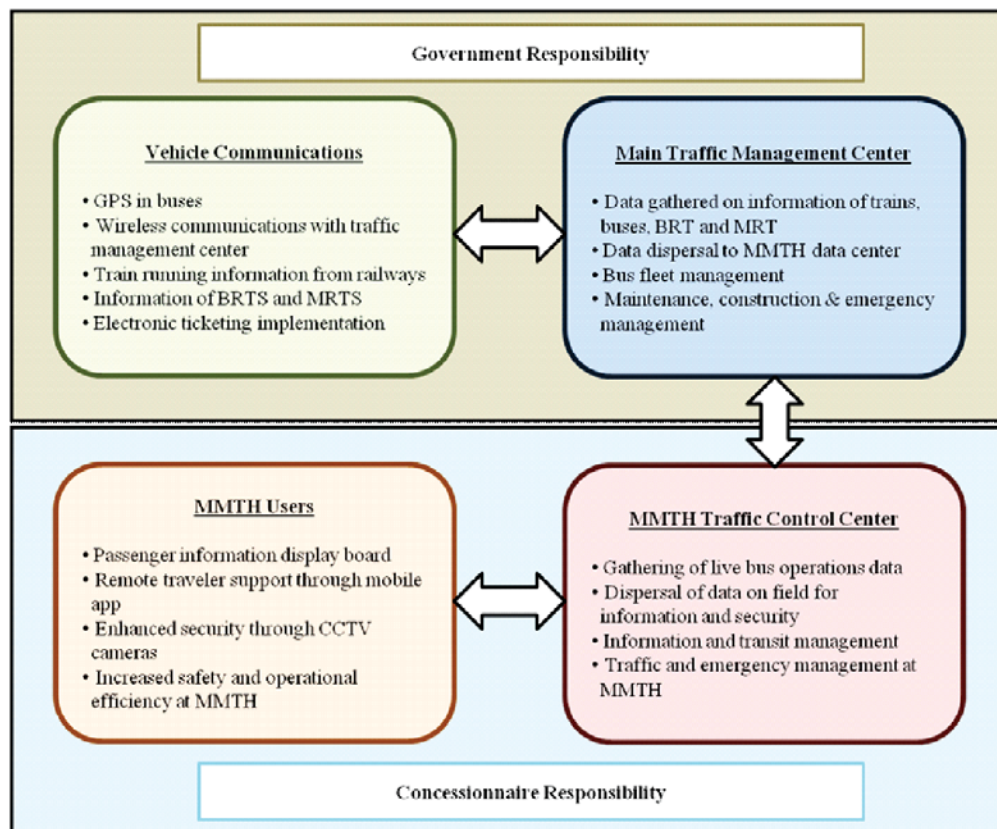


Fig. 3: ITS architecture for MMTH

Based upon the ITS architecture, the implementation of ITS would require close coordination between the government, concessionaire and various other stakeholders. The various agencies and organizations that would be required for successful implementation of ITS would be:

- Department of Transport
- Regional and Urban Planning Division
- Public Works and Utility Division
- Bus Operators
- Internet Service Providers
- Wireless Service Providers
- Department of Information, Technology and Communications
- Police Department
- Mobile Service Providers
- Fire Department
- Ministry of Railways
- Bus Unions and Associations
- Department of Fire and Emergency Evacuation
- Fleet Managers
- Private Players

Close coordination and continuous support from various governmental organizations and private players would be necessary. It is recommended that a special purpose vehicle be formed to integrate and bring all the stakeholders under one umbrella for smooth functioning and implementation of the ITS on the field and to act as a single window of the government for various clearances and approvals. A general responsibility matrix for implementation of Passenger Information System is shown in *Table 1*.

Table 1: Responsibility matrix for ITS implementation

Element	Description	Responsibility
Bus Information	Providing GPS equipped buses	Government
Train Information	Providing Data	Government
Traffic Management Center	Feeding Data to Traffic Management Center	Government
Real Time Information Display Boards at Transit Hubs	Data from TMC to Display Information Boards	Concessionaire
Dedicated Mobile App	Obtaining data from TMC	Concessionaire
CCTV Cameras	CCTV cameras for security and efficiency	Concessionaire
Bus Fleet Management	Tracking movement of buses within MMTH	Concessionaire

4. Development Process of ITS

The ITS architecture as depicted above provides a good starting point for systems engineering analysis that are performed during ITS project development. When an ITS project is initiated, there is a natural tendency to focus on the programmatic and technical details and to lose sight of the broader context. The step by step process for ITS development and integration are shown in *Fig. 4*.

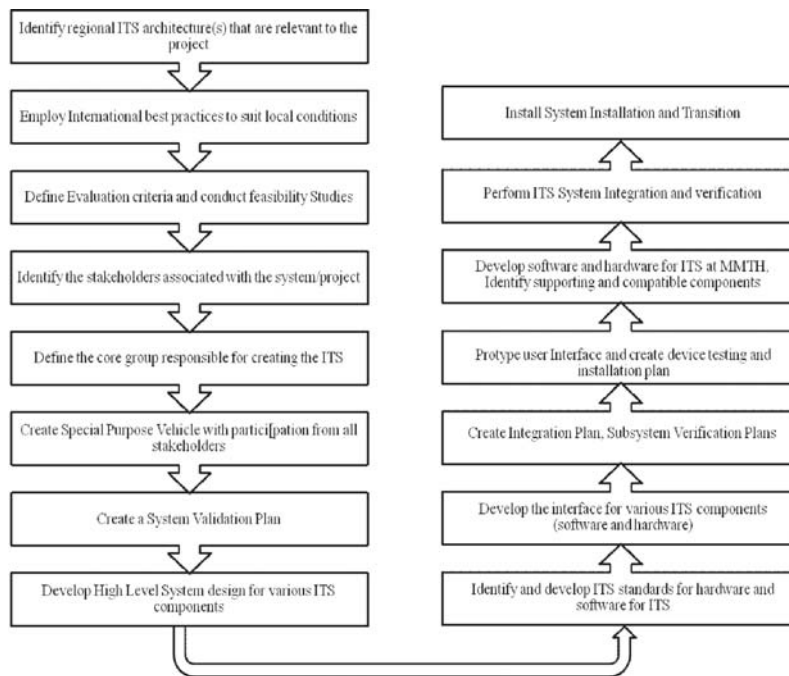


Fig. 4: ITS development flow chart

5. ITS strategic framework

Drawing on the priorities established above and international benchmarking, a strategic framework for the evaluation and development of ITS initiatives would be as under:

- Development of IT Architecture, ITS Standards and ITS Tools
- A sound governance framework
- Appropriate advocacy and support to encourage widespread use



Fig. 5: ITS operation schematic

The concept of ITS can only be developed with close working and coordination between the government agencies, concessionaire, developing contractor and software providers. For understanding the implementation of ITS on field, a schematic is shown in *Fig. 6*. For ease of understanding, responsibility has been split between the government and the concessionaire. Various key responsibilities can be split between the government and concessionaire based on *Fig. 5*.

Government	Concessionaire
<ul style="list-style-type: none"> • Collection of Travel Information from Railways, Buses, BRT and MRT • Single Window to Concessionaire • Installing GPS systems in Buses • Dissemination of travel data to Concessionaire • Coordination and bringing of bus agencies under one umbrella • Coordination and collection of information from railways and seeking requisite clearances • Formation of SPV for all stake holders 	<ul style="list-style-type: none"> • Real Time Information Display Boards at Transit Hubs • Dedicated Mobile App for passengers • CCTV Cameras and other systems for safety, security and ease of operations • 24 hour of monitoring of station and bus terminal • Implementation of extensive Real Time Passenger Notification • Live Bus operations Data • Providing ease of interchange for travellers and users of MMTH

Fig. 6: ITS Responsibility Distribution

6. Initiatives taken by Government of India

An important initiative taken up by Government of India is the “Smart Cities Mission”, launched by Honourable Prime Minister Shri Narendra Modi in 2015. The “Smart Cities Mission” is an urban renewal program with a mission to develop 100 smart cities as satellite towns of larger cities. One of the key tasks under this mission is to provide solutions based on electronic collection of data under various aspects like housing, transport, water, sewerage, etc. Application of smart solutions will enable cities to use technology, information and data to improve infrastructure and services. Under the purview of this initiative, the following pan city ITS proposals were listed for different cities of India, as shown in *Table 2*.

Table 2: Pan City Proposals under Smart City initiative by GOI

S. No.	Component	Cities	Count
1	Centralised Command and Control Centre	Bhubaneswar, Surat, Kochi, Ahmedabad, Jabalpur, Visakhapatnam, Davanagere, Indore, Coimbatore, Belagavi, Udaipur, Ludhiana, Bhopal	13
2	Transit Operations System (Maintenance and Tracking)	Bhubaneswar, Pune, Jaipur, Ahmedabad, Indore, Solapur, Davanagere, Indore, Kakinada, Udaipur, Guwahati	10
3	Smart Parking System	Bhubaneswar, Pune, Jaipur, Davanagere, Indore, Coimbatore, Kakinada, Udaipur, Guwahati, Chennai, Bhopal	11

4	Common Card (Payment and Operations)	Bhubaneswar, Jaipur, Surat, Ahmedabad, Indore, Udaipur, Guwahati	7
5	Area Based Traffic Control	Bhubaneswar, Pune, Ahmedabad, Davanagere, Indore, Coimbatore, Kakinada	7
6	Traffic Mobile App	Pune, Jaipur, Ahmedabad, Indore, Guwahati	5
7	CCTV Surveillance	Pune, Ahmedabad, Devangere, Indore, Coimbatore, Guwahati, Bhopal	7
8	Public Transit and Traffic Operations and Management Centre	Jaipur, Surat, Ahmedabad, Devangere, Vizag, Indore, Belagavi, Udaipur	8
9	GPS Tracking and Optimisation of Routes of Garbage Trucks	Jaipur, Jabalpur, Indore, Kakinada	4
10	Traffic Analysis of Roads and Video Surveillance inside bus using CCTV surveillance	Pune, Indore, Kakinada	3
11	Fleet Management System	Jaipur, Ahmedabad, Indore	3
12	Automatic Fare Collection System (Transport)	Bhubaneswar, Jaipur, Surat, Ahmedabad, Indore	5
13	Variable Message Sign Boards	Ahmedabad, Indore, Bhopal	3
14	Smart Bus stops	Pune, Jaipur, Devanagere, Belagavi	4
15	In-Bus Information System and WiFi	Pune	1
16	Intelligent road asset management	Pune	1
17	e-challans for Traffic Violations	Bhubneswar, Pune	2
18	Bicycle pods with PIS	Devanagere	1
19	Smart paving (capture energy from movement)	Devanagere	1
20	Pedestrian and Bicycle activated signals	Indore	1
21	Smart E- Rickshaw with charging station	Ludhiana	1

7. Challenges Ahead

In India, the ITS market is still in a rudimentary phase and hence there are major challenges in implementing such state-of-the-art technologies in India. As reported by a study done by The World Bank, some of the critical issues for deployment of ITS in developing countries like India are an under developed road network, severe budget restrictions, lack of resources for maintenance and operation, less demand for automation, explosive urbanization and growth and lack of user awareness. While few ITS projects such as advanced traffic management system

using CCTVs, parking information, advanced toll collection, web based traveller information, etc. have been introduced in some of the Indian cities like New Delhi, Mumbai, Hyderabad, Bangalore, Pune, Indore and Chennai; these are stand alone systems working in isolation and not comprehensive or integrated in nature. Some of key challenges that India faces for an integrated ITS are listed below:

Table 3: Key Challenges facing India for an Integrated ITS

- Integration of the various ITS applications along with their components and introduction of national ITS standards.
- Lack of definite guidelines and regulations and difficulties in physical implementation.
- Developing a nation-wide ITS data archive.
- Formulation of national ITS regulatory authority to monitor, regulate and document the upcoming and ongoing ITS projects.
- Setting up a citywide ITS implementations with fully functional Traffic Management Centres for coordination of traffic activities.
- Developing and implementing automated Traffic Data Collection Methodologies.
- India's ITS can't be entirely modelled on the existing successful ITS of other nations due to basic cultural, geographic and practical differences among the countries.
- High cost for ITS safety systems does not allow high penetration. Few people are willing to pay extra for safety systems and only a few technologies are sufficient to ensure safety.

8. Key Drivers for Growth

Some of the prominent growth drivers, for the ITS market in India, are:

- Continuous increase in the number of private vehicles, especially in urban areas of Delhi, Mumbai, Kolkata, Hyderabad and Bengaluru. This leads to traffic congestion, deterioration in air quality, and increase in noise levels in the metropolitan cities.
- Investment of Rs. 26,000 crores for pan city solutions for Smart City Mission.
- Introduction of new public transport systems in Indian cities like Metro Rail, BRT, Monorail, LRT and other forms of public transport. Hence, giving way to new opportunities in Passenger Information Systems, Smart Cards & Integrated Ticketing, and Parking Management.
- Freight is a disorganised sector in India and has huge potential for development. Use of ITS for proper vehicle tracking, vehicle emissions and fuel costs, can help reduce carbon footprint and introduce several degrees of efficiency.

References

1. Smart Cities Mission, Ministry of Urban Development, Government of India <http://smartcities.gov.in>
2. LELITHA V., GITAKRISHNAN R., ASHA A., "Synthesis report on ITS including Issues and Challenges in India", Centre of Excellence in Urban Transport, IIT Madras, 2010, p. 50.
3. TEJAS R., V. DEVADAS, "Intelligent Transport System in India", Journal of Development Management and Communication, Vol. III, No. 3, 2015, p. 304.
4. World Bank; India: Safe, Clean, Affordable and Smart Transport. <http://www.worldbank.org/en/country/india/brief/india-safe-clean-affordable-smart-transport>
5. Traffic Infra Tech Magazine, "ITS Challenges in India", 2015 <https://www.trafficinftratech.com/its-challenges-in-india/4/>

Rapid Urbanisation in India: Development in Transportation Sector



B C Roy
FNAE,
Former Vice President of IABSE,
Zurich.bcroy1944@gmail.com



S Bhattacharyya
Sr. Track & Alignment Engineer,
Systra India

Abstract: Traditionally, Indian urban areas are not planned developments, the old cities expand and engulf the surrounding suburban areas but the available road space doesnot increase. As a result, the travel time increases considerably, incertain stretches the average speed declined below 5 kmph. The affected are the daily commuters, whose travel time shot up, which also affects the pollution due to increased emission and ultimately results in overall decrease in quality of health and life.

Indian city transport infrastructure needs immediate improvement in terms of capacity mobility, speed and comfort. Today's need for the road users is door-to-door service with enhanced comfort, safety and mobility in a cleaner environment. Appropriate public transport systems with proper integration amongst different modes needs to be introduced .The solution space for urban transport is highly restricted on account of most cities being old with congested built-up areas and narrow roads weaving through them.

Keywords: Urbanisation, Transport Planning, Grade Separator, Long Corridor, Bus Rapid Transit System (BRTS), Mass Rapid Transit System (MRTS), Multi-Modal Transport Integration, Traffic Management.

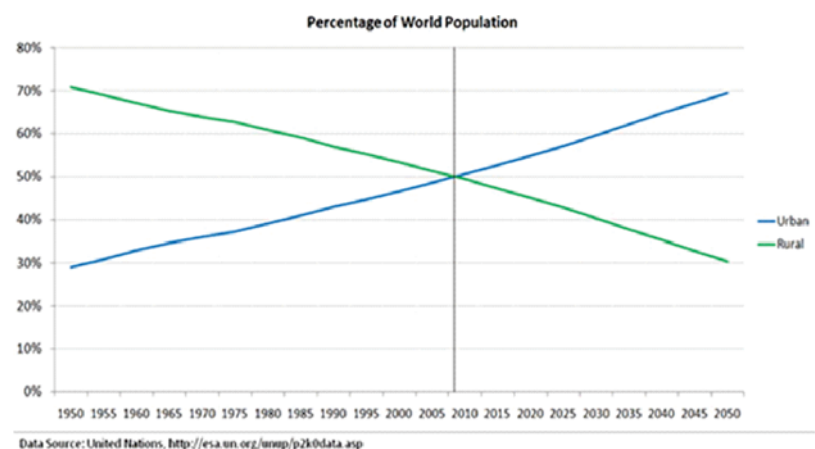
1. Introduction

About a century ago, the ratio of Urban and Rural Population was 1:7 globally. Today, more than half the world's population lives in urban areas.

The population in India increased from 361 Million to 1210 Million within a span of 60 years (Census Data 1951 and 2011); increase in urban population is about twice the rate of increase in overall population at the same time. At this rate, India may be world's most populous nation in around 2030. Though in a few developed countries, like Germany, Japan, and South Korea, the population has started to decline.

Due to such rapid urbanization in the past

50 years many cities are now breaching the threshold of one million population. City limits have expanded as well to accommodate the growing population. Historically, most of the older Indian cities were built unplanned, with offices / business centres built at central place. With rapid expansion of the urban area, most suburban/ rural areas in their proximity have now become part of the greater boundary of the city. People started commuting to the central business area on regular basis; and with increased affordability, use of vehicles increased manifold. The road space being limited and vehicular traffic pattern on Indian roads being highly chaotic, travel time is



getting affected day by day, finding space to route transport corridors through major Indian urban areas has become a daunting task.

Currently, there are an estimated 30 million vehicles on the road which increase by 15%-17% annually and thousands of new vehicles hit the roads every day. With this, the demand for resources to manage traffic is also increasing immensely. The country witnesses about 23 road accidents per thousand vehicles – an alarming figure that is one of the highest in the world. What is making things worse

are highly mixed traffic (i.e. cars, buses, three wheelers, scooters & motorcycles, bicycles, handcarts, etc. competing with each other for available space) and unplanned / poorly planned traffic management.



2. Planning Initiatives

Planning for the solution space is becoming more challenging day by day. Comprehensive Transport Studies and Master Plans are being undertaken to evolve a solution, implementation of which would not exacerbate levels of pollution, increase travel time by forcing long detours or giving rise to pockets of intense congestion, etc.; in a nutshell do not lead to reduction in the living standards of the neighbourhood during the construction phase.

The common guideline for planning such work is as under:

- Improvement programs to be taken up on priority with appropriate resource allocation towards all levels, keeping the Project Affected People to a minimum.
- The solutions must accommodate common and specific features of the cities.
- During implementation of the program, restriction must not be unduly imposed on the existing traffic, environmental and social conditions.
- The work must be completed on fast track with phasing as per the projects requirement.

The National Urban Transport Policy has strengthened the functional hierarchy by bringing the State level policies within the framework of the National ambit. Central and state level planning is initiated for providing efficient urban transport infrastructure. Funding constraints are sought to be resolved through innovative financing arrangements, e.g. promotion of Public-Private Participation (PPP) as a major initiative.

3. Implementation Initiatives

The major requirements of a successful transport system are to meet the demand for safe, convenient, clean and affordable modes of transport that can provide door-to-door service, through seamless multi-modal transfers. Optimization across all modes and forms of transport, capacity augmentation and promoting use of public transport is the need of the hour. This is practiced in two distinct systems: either *through use of same mix of vehicles by improving junctions and segregating traffic dispersal* or *by proposing a separate corridor for exclusive use of vehicle such as Metro/ BRT, etc.*

To prioritize the solution scope, the urban areas are further subdivided into three categories: Mega, Million-plus and Sub-million cities.

In the Mega cities, resort is taken to fast track implementation with sustainable and environment friendly means of augmenting road network capacity like widening, grade separators integrated with mobility plan and elevated corridors, high capacity bus corridors, upgrading suburban rail networks, rail based MRTS, safe pedestrian facilities, and multi-modal integration.

In the Million-plus cities, the improvements adopted are less cost-intensive such as traffic management and intersection improvements - pedestrianization of localities. In recent years, planning for high capacity bus corridors, upgrading suburban rail networks, rail based MRTS, safe pedestrian facilities, and multi-modal integration in Million-plus cities has also started.

In Sub-million cities, the main objective is junction improvement and segregation of traffic and ease of dispersal, although it is high time to develop a Master Plan for grade separated transport system such as BRT/ LRT in such areas to avoid reactive solution once the congestion starts.

The implementation of transportation planning in three Indian mega cities, Delhi, Mumbai and Kolkata, each with a population well over 10 million, and the varied and comprehensive measures being undertaken are discussed. The lower level and less cost-intensive measures being implemented in the Million-plus cities such as Indore are also described in brief.

4. Development in Urban Transportation Infrastructure

4.1 Improving Road Infrastructure to use same mix of traffic:

This improves the traffic intersections to reduce stoppage time and improves its traffic carrying capacity. No specific type of vehicle is adopted in this case; any commuter using private vehicles also get direct benefit from this. In case of cities, grade separator and long corridors are examples of this.

4.1.1 Grade Separators

The densely built-up urban configurations allow increased road areas mainly through grade separators. In India, the cities have executed and continue to execute flyovers across busy junctions along arterial roads where signalized controls are inadequate.

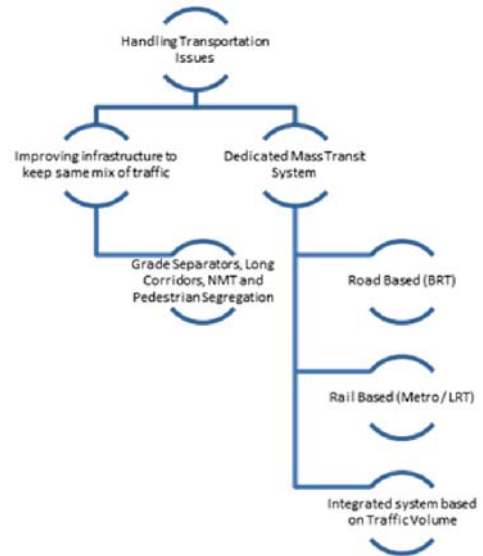
The grade separators can be constructed as elevated cloverleaf or as a system of one flyover and one underpass for straight moving traffic, with ground level rotary for traffics taking right or left turn.

4.1.2 Long Corridors

The effects of grade-separation are highly localized and may contribute to worsening congestions further down the corridor. The problems are being solved only through integration with the overall network. The other option is to make the road elevated or underground for long stretches with appropriate entry and exit points along the corridor. The long corridors increase road area and the journey speed.

4.1.3 Pedestrianization

In another initiative the authorities are trying to segregate the motorized, non-motorized and pedestrian traffic to improve carrying capacity of available road area.



A major problem in the old cities of India is the traffic cutting through heritage areas which also typically house institutions of governance that endanger huge traffic volumes. A solution is to create underground traffic corridors and pedestrianize the ground level. Going elevated, though a cheaper option, may not be acceptable from aesthetic and heritage conservation points of view.

4.2 Dedicated Mass Transit System

Table 1: Choice of Dedicated MRT System

CHOSEN MODE		PPHPD	COST OF IMPLEMENTATION
Rail Based	Metro Railway	>25000	>150 Crore INR/km
	Grade Separated LRT	20000-25000	60-150 Crore INR/km
	At Grade LRT	15000-20000	
Road Based	Grade Separated BRT	10000-15000	15-75 Crore INR/km
	At Grade BRT	5000-10000	

Except for some cities like Mumbai, Kolkata and to a lesser extent Chennai, road based public transport systems carry essentially the whole burden. Therefore, it has become essential to reduce load on the existing system. This is achieved by introducing a dedicated grade separated transport system, for example- Bus Rapid Transit System (BRTS)/ Light Rail Transport/ Metro Rail.

However, to achieve a modal shift, in the interest of augmenting the carrying capacity of particular corridors and also towards addressing the environmental issues, rail based systems such as Light Rail and Metro systems are also being increasingly adopted while one works as inter-dependent ones, each feeding the other, through appropriate modal integration.

4.2.1 Bus Rapid Transport System (BRTS)

For corridors with demand say up to 15,000 PPHPD (persons per hour per direction), a dedicated bus based system becomes an attractive alternative. BRTS is one of the new trends in India and is being planned and implemented in Delhi, Mumbai, Jaipur, Nasik, Hyderabad, and Vijayawada, capital cities or cities with high industrial concentration.

In the older parts of Indian cities even such restrictions do not necessarily work as the available width is even less. The alternative is to further squeeze the widths at grade but taking one of the modes in the other dimension, vertical. It is in such stretches that the alternative of grade separation needs to be investigated for feasibility. This alternative is being adopted in some of the Indian cities.

4.2.2 Rail Based Mass Transit System

When the demand goes up and the passenger trips increases bus transit systems find it difficult to cope with the commuter volume and rail based mass rapid transit system comes into the picture. In the areas where the ROW is narrow, bus based systems are difficult to expand and rail based transit system is the only choice. The metro systems in Kolkata and Delhi are prime examples of effective public transport that have partly relieved the pressure on roads along the corridors.

The basic problem is that these systems are highly capital-intensive and are generally not financially viable on their own. For this reason it deserves extensive and in-depth study before venturing on to one in trying to meet

the mobility requirements. MRTS is planned in phases including its passenger carrying capacity, initially with less number of coaches and adding in as demand increases.

Typical capital costs of metro systems make them unviable as mass transport system as a standalone system but a proper integration with other modes with a common fare structure could make it viable. Thus appropriate feeder systems and multi-modal integration will increase the area served.

4.2.3 LRT model for India

The western LRT model has to be suitably modified to suit Indian conditions. The European model of at-grade LRT is unlikely to succeed in India considering that road users in developed countries are much fewer and much more disciplined. Speed of travel is important. Therefore, if physically segregated lanes cannot be provided for LRT, it should be elevated where necessary, if not all the way. It will add to road space.



Once this modification to western model of LRT is accepted, the need for the expensive low floor LRVs is eliminated. Elevated, LRVs can be with normal floor level and platforms can be provided at the normal height for commuters to board and de-board at level.

When LRT is at-grade i.e. at road level within a dedicated corridor, stations may be located as near to the road junctions as feasible so that the entry and exit of passengers from the stations is through the existing zebra crossings. However, some stations may have to be provided at mid-sections with new signalled Zebra crossings.

5. Delhi Urban Area

In less than 20 years from now Delhi population may increase from 13.8 million to 21 million. Satellite urban areas are developing fast in the south, southeast and eastern fringes and demands for efficient connectivity are increasing. The city network has been developed in a ring-radial pattern, with wide-spread activity centers. Public transport system, mainly road-based and augmented only minimally by suburban commuter rail services, is grossly inadequate. Even with wider roads as compared to other Indian cities, Delhi still offers restricted mobility.



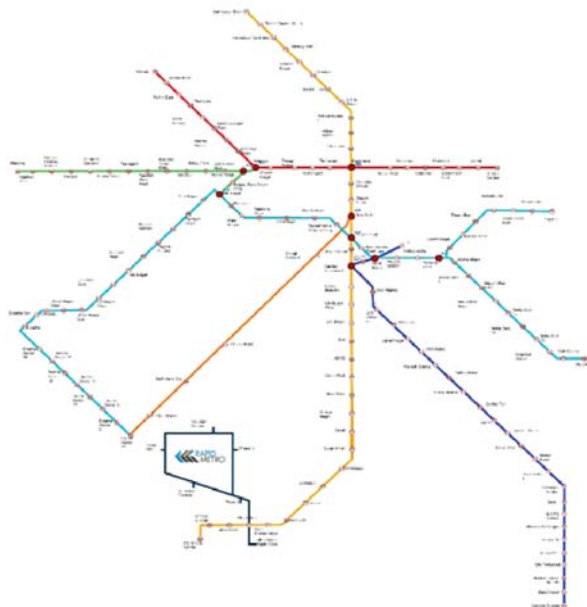
5.1 Improving Road Infrastructure

Flyovers are being constructed at a number of junctions along arterial roads where signalized controls are inadequate. The first four-level grade separator in India provides intersection-free crossing along the ring road and one of the most heavily trafficked radial roads. Pedestrian movement has also been made safer by integrating pedestrian subway with the multi-level grade separator. Execution of this facility, employing top-down construction for the underpass, integrated with the subway, and pre-cast girders for the superstructure of the flyover ensured fast construction and limited the imposition on the environment.

5.2 Dedicated Mass Transit System

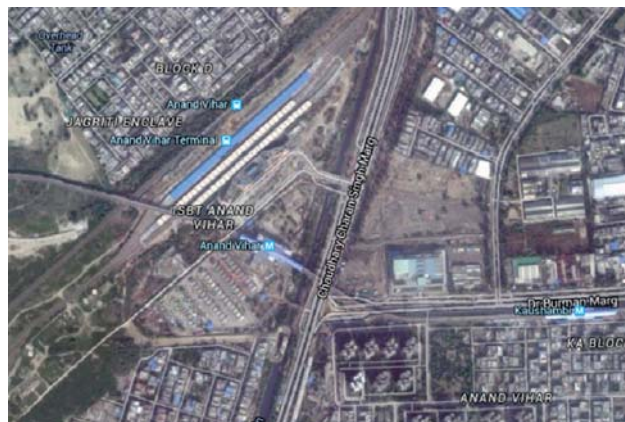
The Delhi Metro system serves Delhi and its satellite cities of Faridabad, Gurgaon, Noida and Ghaziabad in the National Capital Region in India. The Delhi Metro is the world's 12th largest metro system in terms of both length and number of stations. DMRC operates around 2000 trips daily between 05:30 hrs till 00:00 hrs running with a headway varying between 1–2 minutes and 4–10 minutes.

The Delhi Metro was planned to be built in phases spread over around 20 years as with each phase having a target of five years and end of one phase marking the beginning of another. Phase I (65 km) and Phase II (125 km) were completed in 2006 and 2011 respectively, and Phase III is now under construction and is being opened for commuters in phases, while Phase IV is in the planning stage.



5.3 Multi Modal Transport Integration

It is important to promote use of public transport to provide coordinated ticket sales and passenger information for making the transport system cost effective and providing door-to-door service. Under this scenario promoting multi-modal system is inevitable. Presently the public transport system of Delhi is almost entirely road based. With the emergence of MRTS, the bus system acts as a feeder in the MRTS influence areas so that they complement each other. In other areas, the bus system will continue to be the primary mode of public transport.



At Anand Vihar, Delhi there is a model integration of suburban railway, metro station, inter-state bus terminus (ISBT) and city bus terminus. In addition, intermediate public transport (IPT) modes, non-motorized transport are also there in abundance. The pedestrian walkways complete the integration cycle. The connections amongst these modes may not have a single control point but the movement is smooth and convenient.

The next step is to develop a system that is seamless and uses the same fare system for transport. A step towards this is seen in integration of DMRC with the Gurgaon Rapid Metro System, where the same metro card is accepted, reducing the commuter hurdle and the queuing time which enhances the speed of travel.

6. Mumbai Metropolitan Region

The Island City, Mumbai, an 18 km long peninsula surrounded by Arabian Sea, is linked with the mainland by river/creek crossings in its northern reaches. The present population of the greater metropolitan area is 14 million and is projected to be 22 million by early next decade. The transport network, comprising roads and suburban rail system is in the north-south direction and the east-west connectivity is not adequately developed.

Transportation in Mumbai is focused around travel between places of stay and work. The historical development of Greater Mumbai and scarcity of land had resulted in an upsurge in the growth of satellite towns of Thane, Kalyan-Dombivili, Navi Mumbai and beyond along the rail and transport corridor. Mumbai City, due to its geographical constraints has extended in a linear manner. The population of Mumbai generates about 11 million trips per day, the lion's share of which is carried by the public transport system that is available today.

6.1 Improving Road Infrastructure

Recognizing the importance of safe and smooth pedestrian movement in enhancing vehicular travel conditions along with speed, authorities have identified locations for pedestrian grade separators, mainly subways with foot over bridges marked only for those locations where underground utilities pose major problems. Selection and prioritization of pedestrian grade separator was based on study of network traffic situation and socio-economic considerations. Design of the facilities addresses the issue of minimum disturbance to road users, aesthetics and safety.

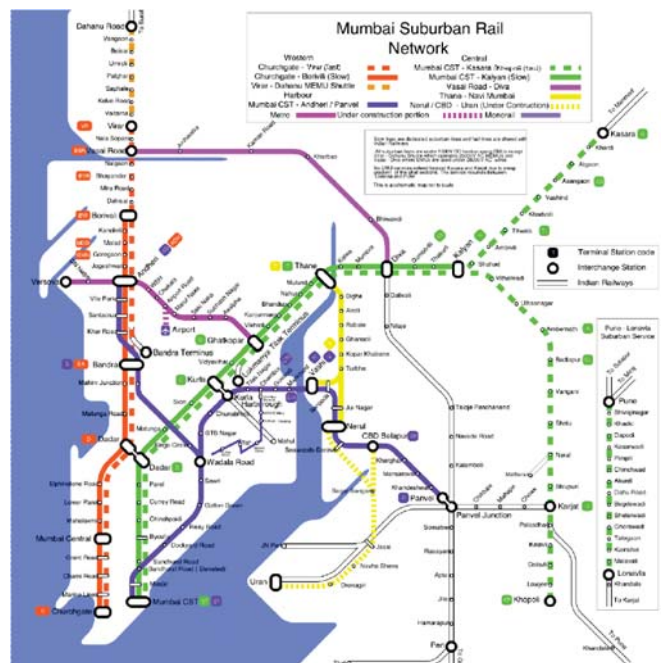
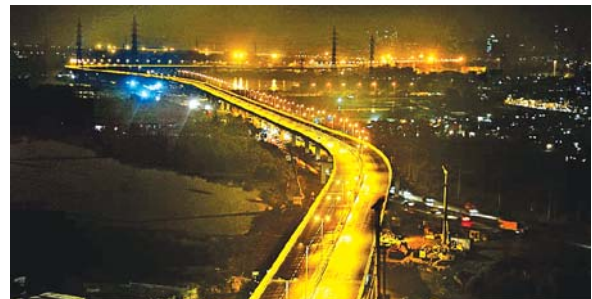
In Mumbai, few elevated corridors were constructed for ease of passage of traffic. New corridors along the coastline of Mumbai Island are being planned. The Sea Link between Bandra and Worli, including a cable-stayed bridge, is a notable one. Appropriate interchanges have been planned to enable access with the city road network system. The Eastern Freeway, implemented along the east coast, provides an important corridor for freight traffic bound to and from the Mumbai Port. The Mumbai Trans Harbour Link (MTHL), a 21.6 km long rail-cum-road link, is planned to provide connectivity between the Island City and the hinterland.

6.2 Dedicated Mass Transit System

Mumbai Metro is a rapid transit system serving the city of Mumbai, Maharashtra. The system is designed to reduce traffic congestion in the city, and supplement the overcrowded Mumbai Suburban Railway network. It is being built in phases and when completed, the core system will comprise seven high-capacity metro railway lines, spanning a total of 174 kilometres.

Operational line 1 of the Mumbai Metro is operated by Metro One Operation Private Limited. While the under-construction lines 2, 4 and 7 will be operated by MMRDA and the underground line 3 also under-construction will be operated by Mumbai Metro Rail Corporation Limited. Mumbai has also an operational Monorail system.

The map shows the operational MRTS system.



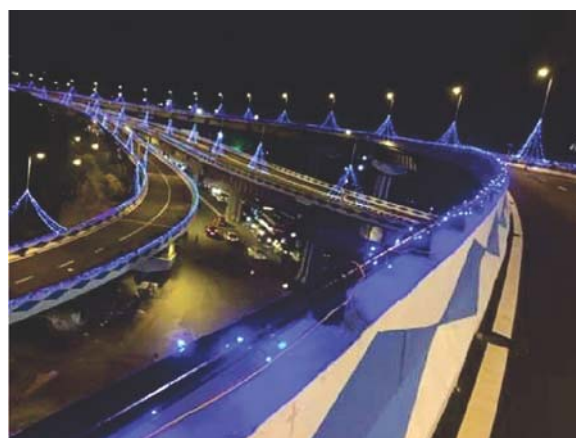
7. Kolkata Metropolitan Region

Kolkata with population of 14.5 million has developed in the north-south direction along the banks of river Hooghly. The transport system in Kolkata is also developed in the north-south direction with less connectivity in the east-west direction. The development of the road network has not been commensurate with the pace of urbanisation and the road area covers only 6% of the city area.

In Kolkata 89% of the commuters use the public transport system comprising both rail and road based modes. Even this is insufficient and measures to develop road and rail based system separately to increase mobility are being taken up in the city. This also includes development of access control corridors within the city to act as arterial network, construction of new river crossings to connect the city effectively with the national highway network and capacity enhancement and addition of new mass transit systems.

7.1 Improving Road Infrastructure

A few flyovers are being constructed in Kolkata to ease the flow of traffic along the already congested road. The right of way being narrow, the construction often drags along considerably beyond the stipulated time frame. An example is the Maa Flyover, built along the Park Circus Connector connecting E. M. Bypass with Park Circus 7-point crossing. A ramp of the flyover is slated to connect with the existing AJC Bose Road Flyover, which will virtually help in making a seamless, no-signal traffic corridor from EM Bypass to Alipore. The total length of the flyover, including the ramps, is 9.2 km. The flyover started its construction in February 2010.



7.2 Dedicated Mass Transit System

The network currently consists of one operational line of 27.22 km from Noapara to Kavi Subhash with five other lines in various phases of construction. The Kolkata Metro was the first metro railway in India, opening for commercial services from 1984. On 29th December 2010, Metro Railway, Kolkata became the 17th zone of the Indian Railways, operated by the Ministry of Railways. There are 300 metro services daily carrying over 650,000 passengers making it the second busiest metro system in India.



After a long pause, the construction of other corridors in Kolkata Metro started. A cross-river facility primarily to connect two busiest rail terminals on the Indian Railway network, Howrah and Sealdah, had become imperative. The alignment traverses a heavily congested area, particularly between these two major rail terminals. The area serviced by this section sports a population of about 3.5 million for whom the new metro facility would be available. Construction of Line 2 started in March 2009.

In 2010, the Railway Ministry announced four new metro link projects for the expansion of Kolkata Metro, totalling a network of approx 146 km. The new links are:

- Joka - B.B.D. Bag
- Noapara - Barasat via Kolkata Airport
- New Garia - Kolkata Airport
- Noapara – Baranagar-Dakshineshwar
- Baranagar-Barrackpore

8. Indore City

Indore is one of the 35 metropolitan cities of India, 14th in rank by population size (2001). It is an important industrial, educational and trading centre of the State of Madhya Pradesh, commanding a large agricultural region providing the needed services and market. Its population has increased from 1.09 million in 1991 to 1.54 million in 2001. It is estimated to reach 4.2 million by 2025.

The per capita income of the people of Indore is medium to high. Mobility of the people is very high with per capita trip rate of 1.49 including walk trips and 1.09 excluding walk trips. Travel Demand by 2025, is estimated to be 6.28 million trips per day. To cater to the future travel demand, at desired level of service and to enable the city to be productive and competitive, extensive development of the transport system is called for. The transport system calls for extensive structures of various types spread all over the city.



Critical traffic problems in Rajwada area were addressed by adopting TSM measures. The Rajwada area is surrounded by commercial establishments and attracts high pedestrian and vehicular traffic. To retain the importance of the historic building and to improve aesthetics and environment, a balance was struck between the transport needs and facilities through traffic management, reorganization of parking and development of pedestrian facilities. The area is proposed to be developed as a pedestrian plaza, with entry for public transport vehicles only.

9. Conclusion

There is a resistance to give public transport dedicated lanes and preferential signalling at road intersections to make the service fast. Hence Grade separated corridor planning with imposing proper traffic management decisions is the only alternative left to decongest the traffic condition. Issues of pedestrian safety and comfort and the physically challenged are being looked at seriously. Sophisticated construction technologies and innovative design approaches are used to have minimal imposition on the environment during implementation. Intensive efforts are underway to promote travel by public mode, through upgrading existing mass transit systems and introducing new systems. Recent times have seen significant initiatives from the private sector in implementing cost intensive projects in transport sector. The Indian urban transport scenario is changing in all its facets and for the better.

10. References

Previous papers published by the Lead Author.

Planning of Lohia Path Chakra Project in Patna, India



Fani Bhushan

Director, Planin Innovations, New Delhi, India

planin.iit@gmail.com

Abstract: *Developing countries like India have unique characteristics and unique restrictions. The objective while planning of Lohia Path Chakra Project in Patna, was to reflect possibilities of creating a new generation of traffic interchanges for congested cities of developing countries like India. It has attempted to merge several innovative concepts of vehicular and pedestrian traffic planning/ engineering with the popular planning/ engineering techniques to generate new techniques. The results are possibilities of some path breaking techniques that might impact how we design pedestrian facilities, bus rapid transit corridors or public transport corridors, pedestrian safety measures and design of interchanges at land starved junctions.*

Keywords: Interchanges, Traffic Engineering, Intersections, Traffic Planning, Innovation.

1. Introduction

1.1 Background

Traffic engineering is comparatively a new branch of engineering that has grown with increase in traffic in recent years. As the vehicular traffic began to increase, the congestion thereby began to hamper the safe and efficient passage/ movement of vehicles and pedestrians. It is therefore, necessary to give attention to the operational characteristics of urban transportation and study the need for improved intersections.

The most problematic part of traffic is the intersection of two roads. A bad design of an intersection can choke a road which can choke the economy of a city. Hence, in view of the importance of intersections and the technologies related to their improvements an attempt was made to innovate at primary level concept. It aims for all intersections to be signal free allowing free movement of vehicles, but that requires use of various interventions or controls. Before proceeding further, it's imperative to discuss few of the existing concepts which have been popular (specially in India).

1. **Rotary Intersection:** A rotary intersection is a specialized form of at-grade intersection laid out for movement of traffic in one direction round a central island. A schematic diagram is given in Fig.1. (A typical four arm rotary intersection for left turning traffic countries). It's clear that a rotary change direct conflict points to indirect ones and helps the traffic to weave off. But a rotary has a certain capacity beyond which it becomes an unviable option (usually 3000-4000 PCU/Hr.)¹
2. **Signal Controlled Intersection:** The next level of intervention is signal controlled intersection. In the signaled intersection when traffic volume becomes too large to handle by a rotary, the queue length reaches next the intersection and the waiting time becomes too long.
3. **Grade Separated Intersection:** Grade separated intersections commonly known as flyovers have been in use and known to all. The schematic representations of various types of flyovers are presented as we proceed further.

Interchanges are generally described by the pattern of various turning roadways or ramps which determine their geometric configuration. They can be broadly classified into the following four basic types:

1. *Trumpet Interchange:* This is for T or Y type of intersection and is the most traditional way of grade separating a three-way junction. (Figure 2) ²
2. *Diamond Interchange:* A diamond interchange is a common type of road junction, used where a freeway crosses a minor road. It is a 4-leg interchange design and is particularly adaptable for major-minor highway intersections. It has many disadvantages, the main being limited capacity because of at-grade terminals on minor roads. (Figure 3) ³
3. *Cloverleaf Interchange:* A cloverleaf interchange is a two-level interchange in which left turns are handled by ramp roads. For cloverleaf design, it is evident that the amount of space/ land required is enormous and still there are 8 divergence and 8 convergence points. i.e. 16 indirect conflict points. (Figure 4) ⁴
4. *Rotary Interchange:* This type of design is particularly useful where several roads intersect and in the locations where plenty of space is available. It requires construction of minimum 2 bridges, and turning movements are accommodated by diagonal ramps. The capacity is like at-grade rotary; hence we can see that both the criteria of high capacity handling and less requirement of land is not being full-filled.
5. *Directional Interchange:* The only type of interchange which follow the natural direction of movement is directional interchange. This type of design requires more than 2 level of interchange or 3 levels of interchange. (Figure 5) ⁵

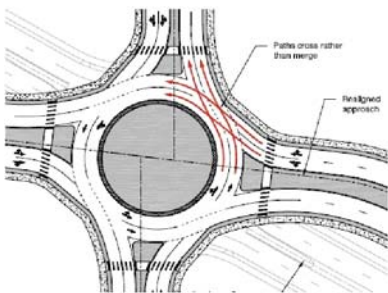


Figure 1- Rotary Interchange

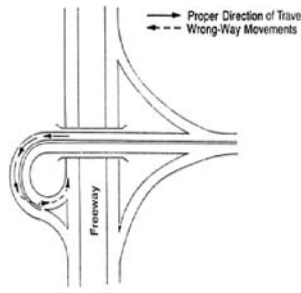


Figure 2- Trumpet Interchange

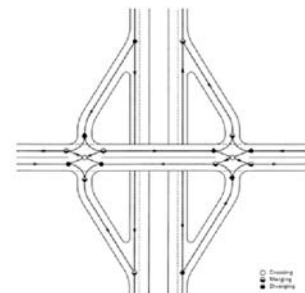


Figure 3- Diamond Interchange

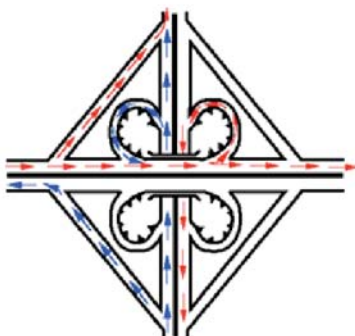


Figure 4- Cloverleaf Interchange

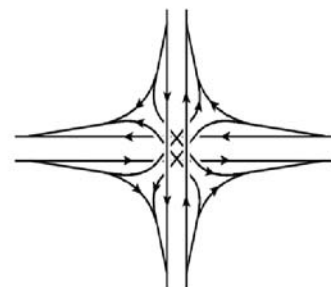


Figure 5- Directional Interchange

Though operationally efficient than the other designs discussed so far, these interchanges are very costly and their options become unviable in developing countries like India because of the distinctive traffic flow, unavailability

of space and requirement of comprehensive solution including pedestrian pathway and bus bays. Most importantly the layout of existing Indian cities with intersections at very close distance, disallow the ramp lengths needed for such interchanges.

India has many old urban areas and its traffic composition is unique. The solution required for such a country needs to be as unique and distinctive as the problem. The existing solutions may not always cater to the requirements of Indian traffic which is a complete amalgamation of pedestrians, hand carts, bicycles, two wheelers, three wheelers, four wheelers, LCV, HCV, etc. all moving simultaneously on the roads which have four-way intersections in approximately every 400-500 meter unlike anywhere else. This leads to congestions and queuing of traffic causing delay in movement up to 8 times of the time expected to cross a junction. In smaller cities, where a citizen crosses a given span of road around four to six times in a day, such delays add up.

The insufficient availability of land prevents many of the existing popular designs for new urban areas with large free space available from being implemented for solving the traffic problems in the cities of India.

1.2 Objective

The principle objective of the paper is to elucidate the planning process of a novel multi-junctional interchange the Ram Manohar Lohia Path Chakra in Patna, which occupies minimum land area (outside the right of way) for its construction at the intersection and is fit for developing country cities like India.

1.3 Methodology

To meet the objective the following steps were followed:

1. The existing situation was discussed,
2. Planning objectives for the project were established,
3. Proposed concepts were compared. and
4. Concept under implementation was compared against the objectives with which it was planned.

2. The Project: Ram Manohar Lohia Path Chakra

2.1 Existing Situation

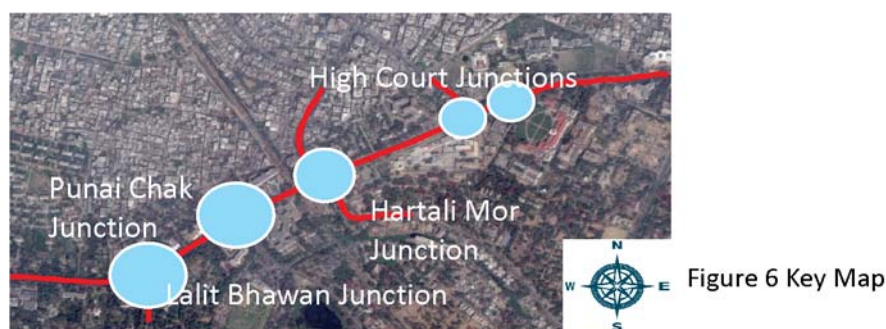


Figure 6- Key Map

2.2 Location

The highlighted area is the project area that is going to be used as the case subject for this paper. The project is named as “RAM MANOHAR LOHIA PATH CHAKRA” (RMLPC). The project is in the City of Patna, which is the Capital of State of Bihar, India. The central spine of the project is popularly known as Bailey Road, which

is the main arterial road of Patna and cuts across on the East-West axis. It's important to note that Patna as a city has organically developed along the East West axis on the southern banks of the river Ganga. On the eastern side is the older parts and the western side is the newer and expanding Patna. Bailey Road runs almost parallel to the river. This feature makes Bailey Road an extremely important road in development planning of Patna as a city. The project starts near the zoo on the west end side as seen in Figure 6 Key Map, and stretches up to the Income-Tax Office on the east end side of the Bailey road. The road connects CBD of Patna, Maurya Lok and the Railway Station on the east end to the New Capital Area of Patna, the main administration area of the capital which is towards its west end. The distance between the west and east ends is approximately 3.0 km. The five intersections along the Bailey Road are Lalit Bhawan Junction (three-arm intersection), Punai Chak Junction, Hartali Mor Junction and High Court Junctions (three-arm intersections). The interesting point is that even though the traffic volume was less than 10,000 PCU/Hr for all the intersections in 2013 and the available ROW were sufficient for catering to such traffic, the mix of traffic and road geometry led to delays at every junction. Recurring use of the stretch/day by same set of people made these delays very significant and it became imperative to create a multi-junctional interchange for the stretch.

Lalit Bhawan Junction:

It consists of Bailey Road (ROW-60 m) along the East West alignment and Circular Road along North-South alignment. The Circular Road (ROW-30 m) provides the link between the airport and the city. Besides, there is a lot of political leadership movement along the circular road as it is one of the most accessed roads by the Chief Minister and the Governor of Bihar.

Punai Chak Junction:

Bailey Road (ROW-40 m) is crossed by a minor road (ROW- 20 m). This unnamed local road connects the administrative secretariat to the state's technical secretariat, with important state ministries and department housed on both the sides. Thus there is a day long criss-cross movement of both pedestrians and vehicles at this junction.

Hartali Mor Junction:

The Junction has Bailey Road (Row-60m) along East-West alignment, Boring Canal Road (ROW- 40 m) going towards North Side up to the banks of river Ganges (on the North of Bailey Road). To the South of Bailey Road is Serpentine Road alternatively also known as Daroga Rai Path.

High Court Junctions:

It's a set of staggered three arm intersections between a road on the North (ROW- 20m) of Bailey Road (ROW- 30 m) called Boring Road and another local road on the South (ROW- 20 m) which is the main access to the Patna High Court. The Presence of the High Court at the junction makes the traffic characteristics complex at these junctions.

2.3 Land Use

The stretch has institutional land use along both its side, with government administrative buildings primarily as shown in the Fig 7.

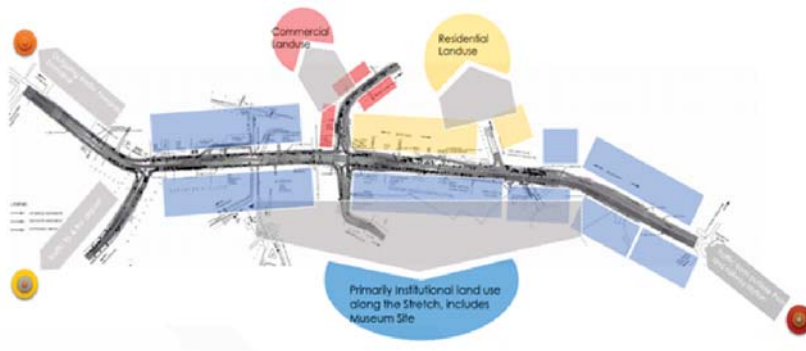


Figure 7

2.4 Site Constraints

Hartali Mor Interchange: Problems, Constraints & Limitations

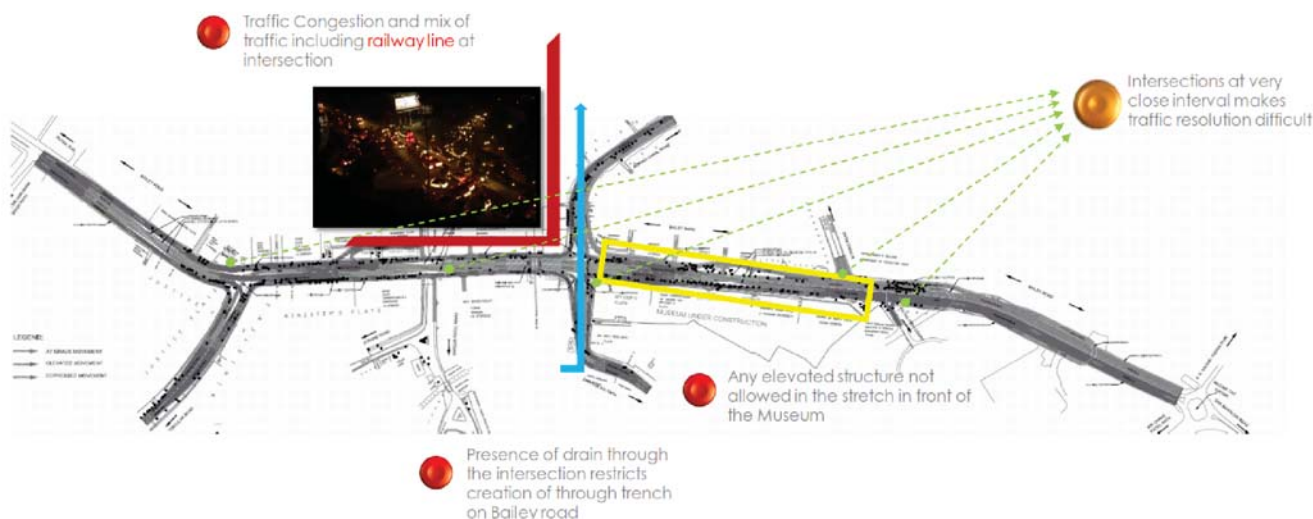
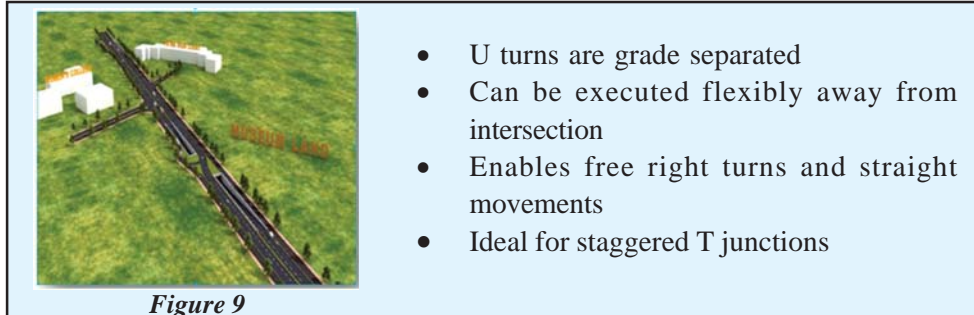


Figure 8

Presence of Railway Line: A local train passes the intersection on grade two times a day. The traffic and gate must be closed for the train for approximately 5 minutes each time. A drain of 3m diameter passes through the central line of Boring Canal Road and the Hartali Mor junction. The average distance between two consecutive intersection is less than 500m. Elevated structures on the road were not allowed near Patna High Court and in front of the Museum Building

2.5 Planning Objectives for the Project

- To make the stretch free of signals or manned traffic regulation,
- To ensure pedestrian crossings near intersection without any conflict with vehicular traffic on the through road (Bailey Road),
- To contain any construction by availing minimal land outside the ROW along the Bailey Road and no land acquisition from private land ownerships along Boring Canal Road,



- U turns are grade separated
- Can be executed flexibly away from intersection
- Enables free right turns and straight movements
- Ideal for staggered T junctions

- To provide a corridor such that the public transport of Intermediate Public Transport vehicles can have dedicated stations,
- To provide for separate drainage for the project and developments adjacent to the road,
- To provide a basic utility corridor for future laying of electrical and telephone/ optical fiber cables, and
- To provide aesthetics which can raise the developmental aspirations of the public.

2.6 Concepts Considered:

2.6.1 Rotary Based Interchanges: Two corners of Hartali Mor junction have important buildings - Pant Bhawan and Museum. No land was available for making a rotary of desired radius that could have catered to a traffic volume greater than 5000 PCU/hr. Foot over bridges or pedestrian underpass were needed for catering to the pedestrian movements. Mix of traffic included more than 30% of slow moving vehicles being part of the local movement. Provisioning for bus stops and auto stops at both end of the Junctions was adding further weaving movement and traffic flow disturbances.

2.6.2 Clover Leaf Interchange at Hartali Mor Junction and Rotary at other Junctions: Insufficient land availability prevented this solution from being implemented at Hartali Mor. The length available for the ramp was far too less because of the presence of the railway line near the junction.

2.6.3 Through Depressed Corridor for Bailey Road with At Grade Rotaries: This would require an underpasses with 5.75 m of clear height clearance near the rotaries. The ground water level in Patna being very high and the general topography of Patna and the site made it extremely prone to flooding. Drainage was also problematic. The risks associated with failure of drainage during high down pour ruled this possibility out.


2.6.4 Through Elevated Corridor along Bailey Road with At Grade Rotaries: The presence of the railway line at the Hartali Mor Junction would require an ROB with ramps stretching up to the Museum building. Elevated structures on the road were not allowed in front of the Museum and the High Court. Hence the concept was ruled out as well.

2.6.5 Grade Separated U-turns: Consecutive U-turns were provided away from intersections enabling right turns and allowing through traffic to remain at grade, yet resolving the traffic congestion.

3. Innovative Traffic Interchange

Swap Based Traffic Interchange [SBTI] (PATENT No. 261788)⁶

Traffic streams are swapped before intersections at appropriate distance where such opportunity exists. This allows right turn to be executed without coming in conflict with other traffic movements at the intersections. Left traffic movement is kept out of the intersection, maintaining separate lanes.



- Adjacent traffic moving in opposite directions are swapped for their lanes
- Can be executed flexibly away from intersection
- Crossover length can be reduced and controlled
- Enables free right turns and straight movements

Figure 10

3.1 Proposal 1:

Salient Features: Combination of grade separated U turns and Swap Based Interchange along the Bailey Road. The proposal can be best explained through the pictorial depictions in Figures 11 -14.

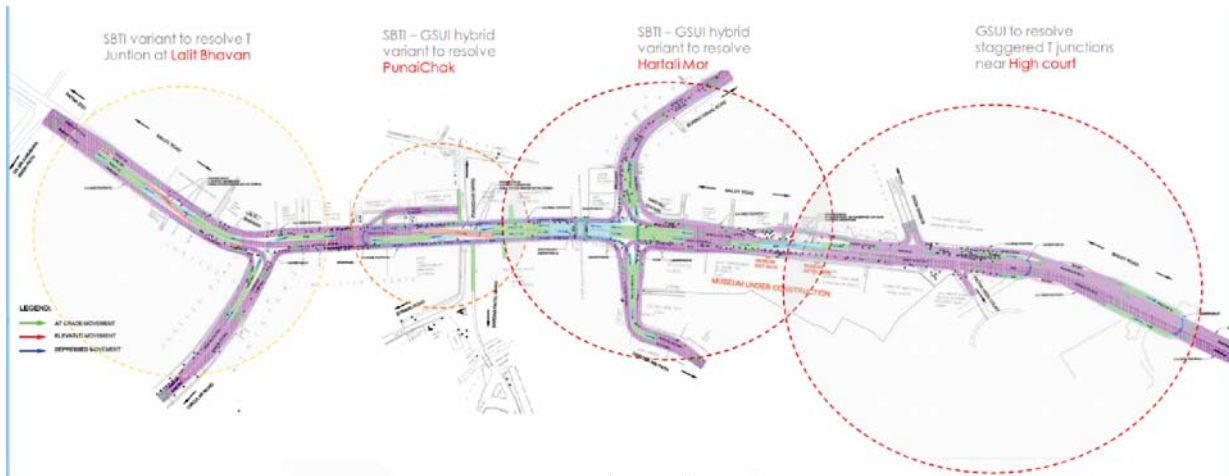


Figure 11



Figure 12

The first ever SBTI was used at BPSC, away from Lalit Bhawan so that the traffic can change the lanes in opposite direction ensuring free right turning movement at the intersection at Lalit Bhawan (T junction).

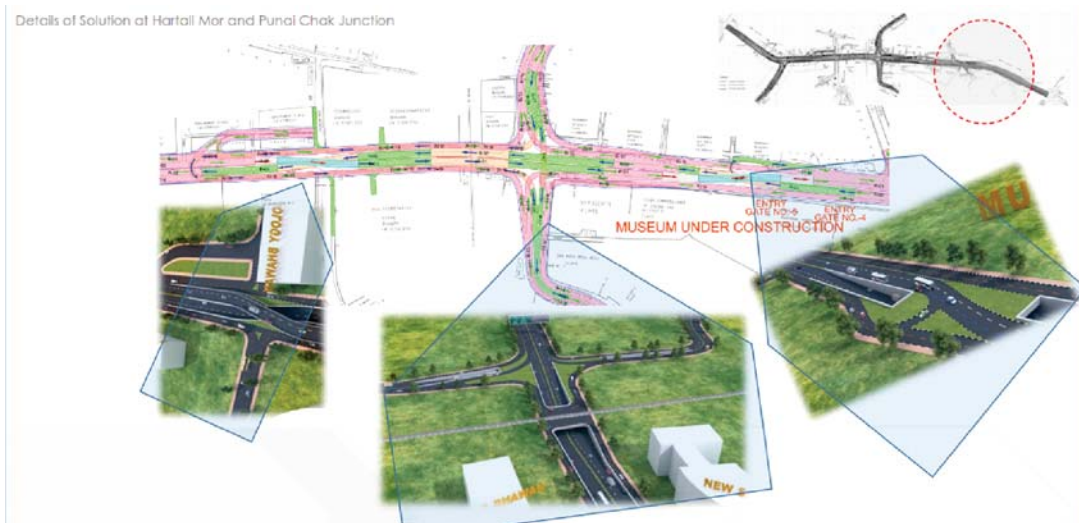


Figure 13

A hybrid of SBTI and GSUI variant was used at Punai Chak to free all right turning movement without intercepting with the through traffic.

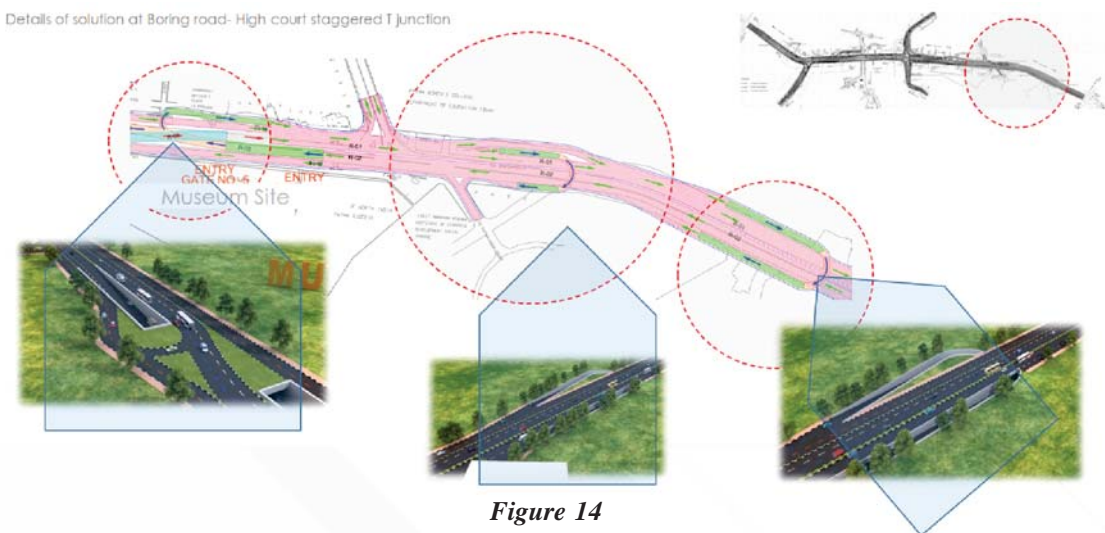


Figure 14

3.1.1 Planning Objectives met in the proposal and how:

To make the stretch free of signals or manned traffic regulation: On Bailey Road, near the High Court end (eastern end of the project), the staggered T Junctions were resolved using “U turns “ of sufficient tuning movement radius on both sides of the junctions, away from the junctions to provide for merging, demerging of the traffic. Thus all the right turns were catered to through the “U Turns”.

Hartali Mor was negotiated using swapping of traffic in front of the Museum and Punai Chak. The swaps caused the right turns from Bailey Road to the intersecting roads to be free. Punai Chak could not be resolved. Lalit Bhawan was resolved using a swap and a straight bridge on Bailey Road.

To ensure pedestrian crossings near intersection without any conflict with vehicular traffic on the through road (Bailey Road): Underpasses and Foot Over Bridges were provided along the stretch. These are standard ways of providing pedestrian facilities and no innovation was involved.

To contain any construction by availing minimal land outside the ROW along the Bailey Road and no land acquisition from private land ownerships along Boring Canal Road: This objective was achieved partially. The “U-Turns” took more than the available ROW for sufficient turning radius. As there were no other loops involved, no extra land was needed at any other intersection.

To provide a corridor such that the public transport of Intermediate Public Transport vehicles can have dedicated stations: A separate corridor could not be provided due to the nature of the solution. Non weaving movement of buses or ITP vehicles was not possible with swapping movement along the Bailey Road. Also planning of bus bays/ auto stops became an issue due to the configuration adapted for the project.

To provide for separate drainage for the project and adjacent developments: A separate drainage with dual section (chamber) was planned under the footpath throughout the project. One section, collecting water from adjacent buildings catered to the municipal drains and the section having water inlet from carriage way side catered for the stormwater drainage. Electro-mechanical pumps and sumps were provided near depressed areas for pumping out of the water. Provision for additional pumps, diesel based gen-sets and pumps mounted and operable from vehicle engines were planned for any emergency. Water proofing of underpasses was given special attention and proprietary material were proposed for the same.

To provide a basic utility corridor for future laying of electrical and telephone/ optical fibre cables: Utility corridor could not be provisioned in the planning

To provide aesthetics which can raise the developmental aspirations of the public: Aesthetics were added through hard and soft landscaping near traffic islands and unused pockets of land along the project site. No special provision was made.

3.2 Proposal 2:

The project uses Swap Based Traffic Interchange, Semi Depressed Rotary with Semi Elevated Throughway and Semi Depressed Rotary with Semi Elongated Throughway. The proposal can be best explained through the pictorial depictions in Figures 15-19.

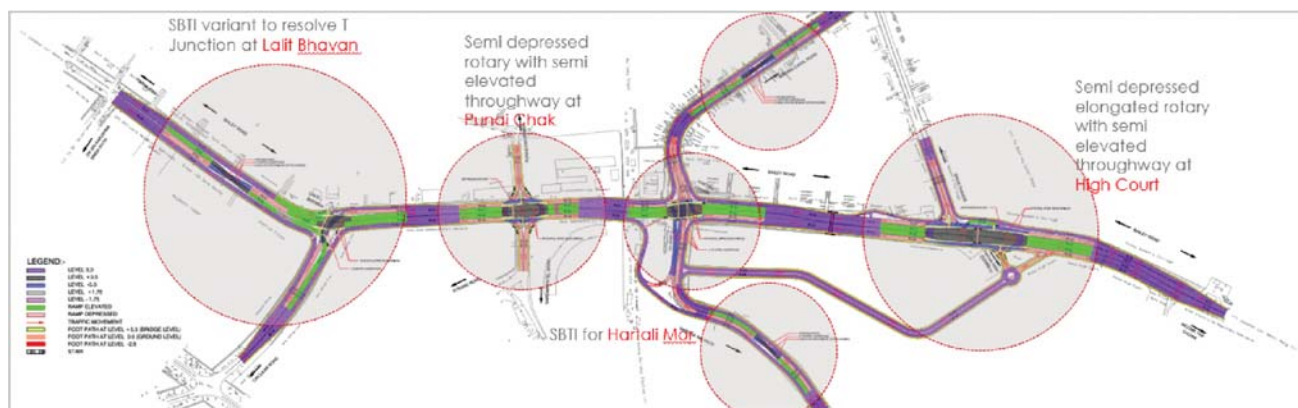


Figure. 15

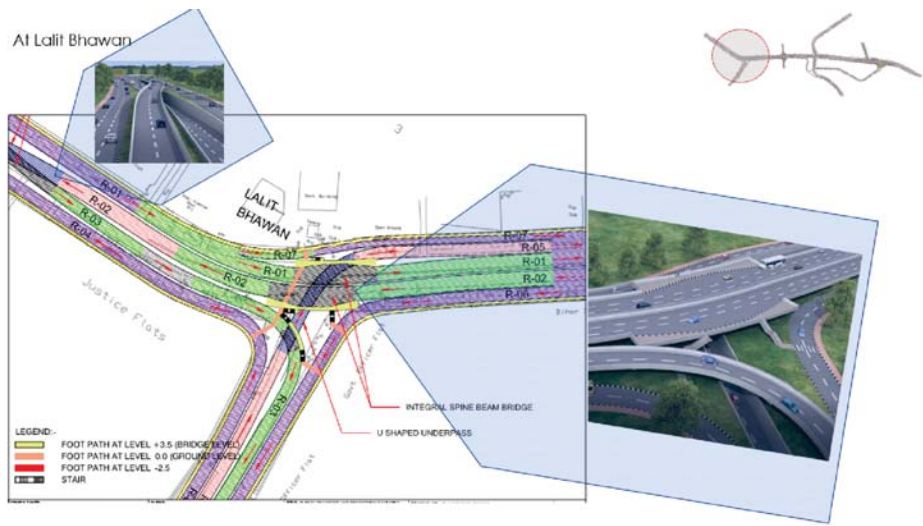
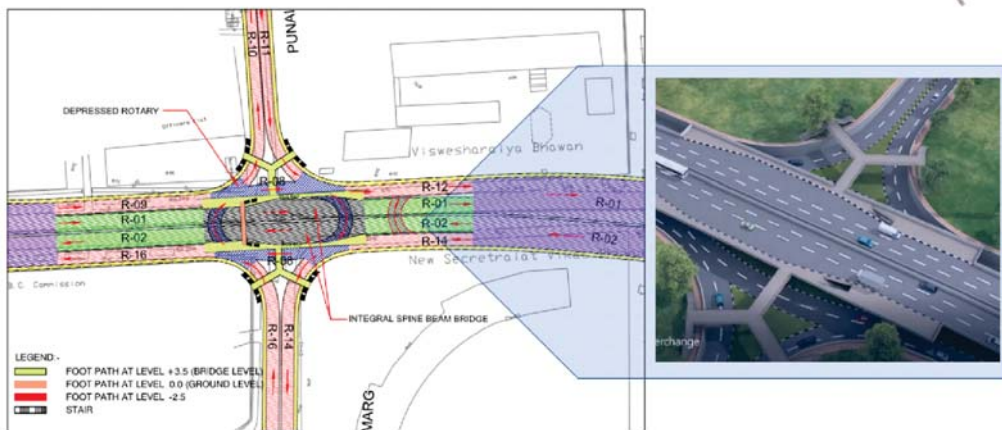


Figure 16

At Punai Chak



At Hartali Mor

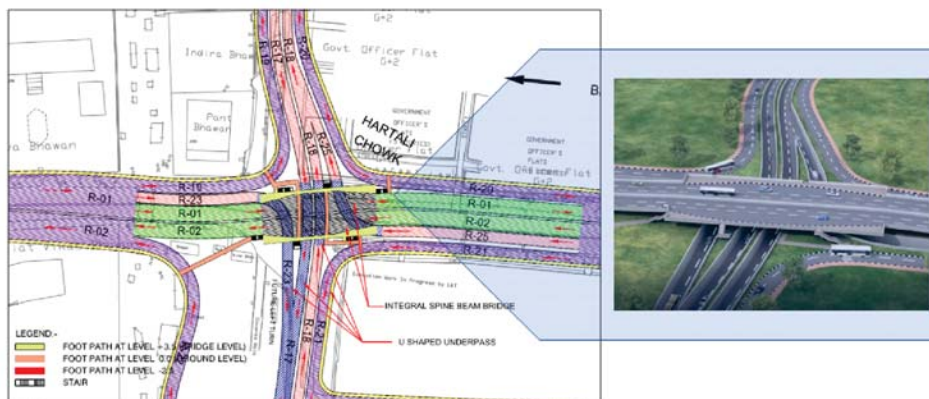


Figure 18

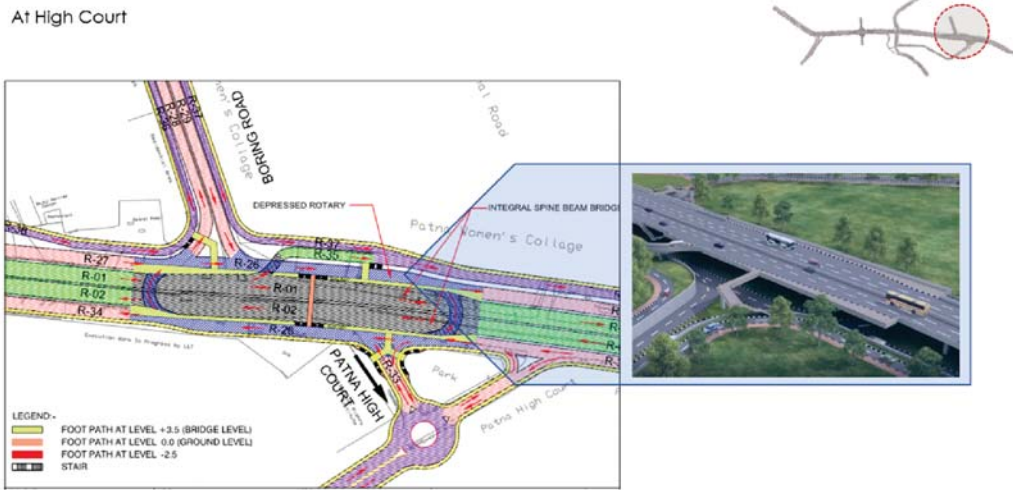


Figure 19

3.2.1 Planning Objectives met in the proposal and how:

To make the stretch free of signals or manned traffic regulation: This objective was achieved by adopting different strategies for different intersection. A major change in approach was to put the Swap Mechanisms on Serpentine Road and Boring Canal Road. Bailey Road was freed of any unusual structure.

It was not seemingly possible to make flyovers at Lalit Bhawan, Punai Chak, Hartali Mor and the High Court. Hence the roads intersecting these junctions were depressed by 2.75 meters. That allowed the flyovers to rise about 3m above ground and yet achieve full clearance. The need for ramp length was thus accommodated, allowing elongated rotaries to be created freeing the turning movement of local traffic and allowing the through traffic cruise over the flyover.

Lalit Bhawan was resolved using a Swap and a Straight Bridge on Bailey road. At Lalit Bhawan an additional Bridge was added alongside of the through straight one, to provide a better turning radius for the right turning movement from Circular Road, better alignment for traffic movement making a right turn from Circular Road to Bailey Road.

To ensure pedestrian crossings near intersection without any conflict with vehicular traffic on the through road (Bailey Road):

Because of the semi depressed – semi elevated construction adopted for vehicular traffic, it became possible to provide an approach to the pedestrians paths (which remained at ground level) from the elevated structures. The illustration can be elucidated through Figure 20. Insets A and D are connecting the bridge portion to the footpath. Hence, only 3-3.5m rise was necessary for pedestrians. Insets B and C are hanging pedestrian

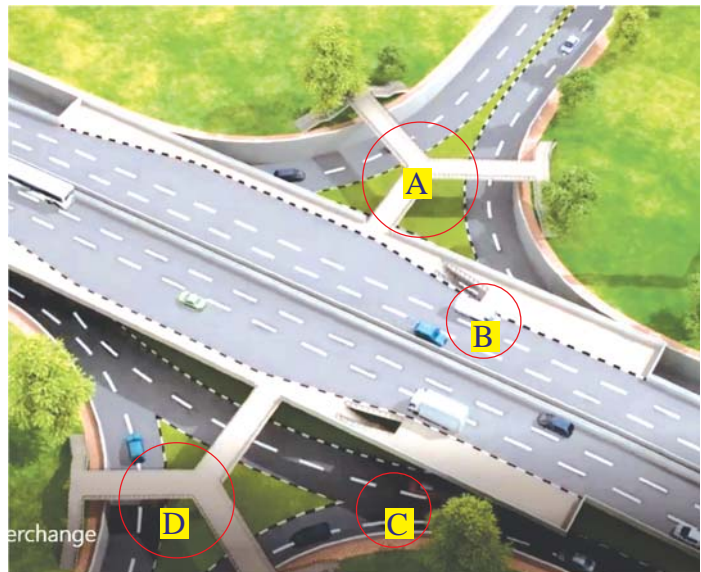


Figure 20

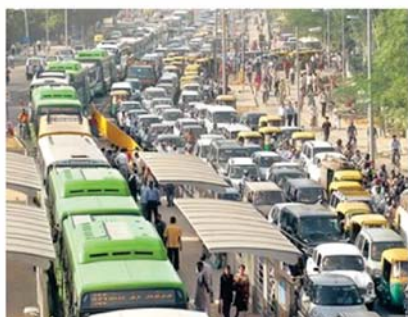
crossings below the bridge, providing clear pedestrian path through Bailey Road without any vehicular intervention. Hence, a unhindered pedestrian movement was possible at the intersection.

It is important to point out that this innovation helped create a pedestrian system which is more efficient than the regular foot over bridges found at many locations as seen in the picture.



To contain any construction by availing minimal land outside the ROW along the Bailey Road and no land acquisition from private land ownerships along Boring Canal Road: This objective was achieved as all the structures involved in creation of the project were along the ROW of the project. One loop was provided near Hartali Mor, that went through unused government land. Technically it was possible to avoid that loop but for the site feasibility purposes the loop was chosen.

To provide a corridor such that the public transport of Intermediate Public Transport vehicles can have dedicated stations: A separate corridor could be provided. The left most lanes of the through lanes on both sides of the Bailey Road were chosen for that. The need for public transport vehicles and ITP vehicles to weave with through traffic was avoided by providing Dedicated Bus bays/ stops on the bridges itself. An additional lane width was provided on the summit part of the Bridge for buses to stop. This is illustrated in the pictures. The bus bays were fully integrated with pedestrian access, that too at a very low height, making the stops a lot more meaningful. The bus stops being at the junction itself, took away the urge to stop the bus or the autos on either side of the ramp, which would be difficult for the pedestrians since access would be very difficult. Hence, Bus Stops were incentivised with full weather cover, extra dedicated lane with, zero distance from intersection and complete pedestrian connectivity. At the same time any other point on the corridor was disincentivised by the road gradient and absence of pedestrian connectivity.



Popular version of corridor with bus stops along the median away from intersection without pedestrian connectivity.



Proposed version of corridor with bus stops along the leftmost through carriageway exactly above the intersection with full pedestrian connectivity.

To provide separate drainage for the project and adjacent to the road: A separate drainage with dual section (chamber) was planned under footpath throughout the project. One section, collecting water from adjacent buildings catered to the municipal drains and the section having water inlet from carriage way side catered for the project storm water drainage. Electro-mechanical pumps and sumps were provided near depressed areas for clearing out of the water. Provision for additional pumps, diesel based gen-sets and pumps mounted and operative from vehicle engines were planned for any emergency. Water proofing of underpasses was given special attention and proprietary material were proposed for the same.

Additional provisioning of sump below the underpass ramps was provided for storage of two hours of down pour at the rate of 100mm/hour. This was part of a mitigation strategy suggested to us by our structural design partner B&S Engineering Consultants Pvt. Ltd.

To provide a basic utility corridor for future laying of electrical and telephone/optical fibre cables: A utility corridor of 2m width was provided along the median of the Bailey Road, all through the project. Cross channel pipes were provided at regular interval for connecting two ends and the median corridor.

To provide aesthetics which can raise the developmental aspirations of the public: Elevated part of Swap structures were designed as extradosed structures imparting aesthetics to the structures themselves. Also, the bridges were kept integral in design approach with relatively sleek slabs. That not only reduced the required ramp lengths but also provided greeter aesthetics to the whole project. Special lighting and landscaping efforts were made to improve the aesthetics further.

Comparative Analysis of Proposal 1 and Proposal 2 & Other Concepts

Concepts	Proposal-1	Proposal-2
To make the stretch signal free of manned traffic regulation	Yes	Yes
To ensure pedestrian crossings near intersection without any conflict with vehicular traffic on the through road (Bailey road)	No	Yes
To contain any construction by availing minimal land outside the ROW along the Bailey road and no land acquisition from private land ownerships along Boring Canal road.	Yes	Yes
To provide a corridor such that the public transport of Intermediate Public Transport vehicles can have dedicated stations	No	Yes
To provide separate drainage for the project and developments adjacent to the road	Yes	Yes
To provide a basic utility corridor for future laying of electrical and telephone/OF cables	No	Yes

4. Conclusion

India is a unique country with its unique characteristics in every way which includes the traffic problems. The solutions required for its traffic congestion also need to be unique. The structural engineering required in the design solution hence needs tremendous improvements and should also be cost-effective.

Proposal- 2 has been selected for implementation by the Implementing Agency, the Bihar Rajya Pul Nirman Nigam Ltd. The project is under construction currently at multiple fronts. It's worthwhile to applaud their initiative to adopt such innovation for the city of Patna, which can arguably have claimed to be unique in the world as of today.

Innovation is an infectious attribute and as we are moving ahead with the construction of the project. A new way of pedestrian crossing has been invented (Patent CBR No: 19301)⁷ which meets all the needs of the distinctive issues which the project was facing. But it's difficult to implement these innovations the first time because most of the challenges remain unknown till late hours. These innovations cannot be successful unless all involved disciplines of engineering contribute with extra effort to make the new concepts work, as has been in the case of Ram Manohar Lohia Path Chakra. Readiness to endure a substantial structural design effort towards achieving the goals has made the project live.

5. Citations

1. The Highway Code: Government of the United Kingdom June 27, 2014. Retrieved November 8, 2014
2. Federal Highway Administration Research and Technology: <https://www.fhwa.dot.gov/publications/publicroads/02sep/06.cfm>
3. Impacts of Replacing a Tight Diamond Interchange with SPUI- Sina Vadaei, Portland State University
4. Lecture Notes by Prof. Tom V Mathew: https://www.civil.iitb.ac.in/tvm/1111_nptel/567_Grade/plain/plain.html
5. Online Manuals: <http://onlinemanuals.txdot.gov/txdotmanuals/rdw/freeways.htm>
6. Fani Bhushan, “Swap Process for Interchange and Traffic Management” (Patent No. 261788)
7. Fani Bhushan, “Pedestrian Integration at Cross Road” (Patent CBR No: 19301)

KOCHI METRO RAIL was inaugurated by PM Narendra Modi on 17th June 2017, alongwith Mr E Sreedharan, the pioneer for Metro rail systems in India, and other political dignitaries.

Kochi Metro Rail Corporation (KMRL) completed the construction of its first phase, the longest first phase metro in India, in a record time of 45 months. Of a total length of 26 kms, the first phase of the metro will run for 13 km and cover 11 stations between Palarivattam and Aluva in Kochi. The cost of the entire metro construction was about Rs 6000 crore, with execution by DMRC and to be operated by KMRL. The first phase will include feeder services with boats, called as Water Metro, which was set up at a cost of Rs 800 crore. The first phase of the integrated public transport system will also have buses, for which the existing bus network was restructured.

The **Kochi Metro** has a strong commitment towards clean energy, and it is the first metro service in the country to leverage solar power to meet a quarter of its electricity requirements. With every one of its 23 stations having solar panels, which can generate 2.3 mega watt (MW) and a 4 MW solar plant, plans are underway to meet as much as half of its electricity demands through solar power.

Also, every sixth of the 4,000-odd metro pillars will have a vertical garden which will use recycled municipal waste. It has offered employment to a large number of transgenders, twenty-three of whom have been hired for operations ranging from ticketing to maintenance. It will also be the first Metro in India to have a workforce that comprises 80% women.

Future Shapes of Bridges in Urban Environment



Max MEYER, Dr SC. h.c. ETH
VSL International
Max.Meyer@vsl.com

Abstract: *Improvement of physical mobility in cities is a big challenge. This paper investigates how approach to design and construction of elevated traffic corridors needs to evolve to meet the challenges of the future.*

Keywords: aesthetics, constructability, carbon footprint

1. Introduction

Even so virtual mobility is becoming more and more important, enabling physical mobility in urban environment is and will remain a major necessity for cities to remain or become attractive places for living and for working. Due to lack of space new pedestrian, vehicular and rail links can often not be built at grade any more, but need to be moved below or above ground. Subject of this paper is to talk about the challenges with regard to building such links above grade on bridges focussing on the following three aspects:

- impact on a city's architecture
- impact on city dwellers during construction
- carbon footprint during construction and operation

2. Aesthetics of bridges

2.1 General: Bridges are huge structures, which in urban area are normally above at grade road corridors. Its visual impact on commuters at grade is huge. Bridges obstruct free view on surrounding buildings and the sky, restricting sun exposure and growth of vegetation. All these comments show, that integration of bridges into an urban area in an architecturally satisfying matter is a demanding task. Since bridges are built to last for 100 years or more, they do impact urban architecture for decades.

2.2 Road bridges: Roads are either elevated only locally on flyovers to remove level crossings with other roads or elevated over extended length on viaducts to increase capacity of existing at grade roads. Flyovers are easier to integrate into surroundings than viaducts, since they are of relatively short length and have constant width. Intersections they cross are by definition wide open areas. Viaducts on the other hand have on and off ramps, where typical road section has to be significantly increased. Available road corridors are often narrow resulting in a scenario, where the elevated viaduct creates for the existing at grade road and the lower 2 to 3 storeys of buildings along the road a tunnel effect. Hence it may not always be advisable to increase vehicular capacity in existing corridors by construction of viaducts.

2.3 Rail bridges: When rails are elevated in urban areas they normally run over many kilometers on viaducts. These viaducts are typically only 9 to 10 m wide. Hence they are easier to integrate into existing road corridors when compared with road viaducts. The same can however not be said about the elevated stations, which are required at intervals of about 1 kilometer along a viaduct. Stations are huge structures, which are significantly wider than the standard viaduct.

- 2.4 Pedestrian bridges: They are clearly the easiest to integrate satisfactorily into an urban environment.
- 2.5 Design and detailing: Once a decision has been made, that a bridge or a viaduct shall be built to increase mobility, it is the design engineer's duty to ensure, that the structure she/he is designing does blend well into the surrounding area and enhances its environment. This can be achieved with relatively small amount of extra costs, if basic aesthetic principles are observed already during the conceptual design phase.
- 2.5.1 Deck: During conceptual design phase not only structural function of deck has to be looked at but designer needs to fully appreciate all the furniture the deck has to carry like parapets, noise barriers, drainage pipes, light posts (for road bridges) and catenary masts (for rail bridges). Only when looking at the entirety of all these aspects an informed choice of the most suitable deck section can be made, which is structurally efficient, easy to build, economical and also aesthetically convincing. Another important consideration to arrive at aesthetically pleasing structures is to smoothen out any kind of transitions like e.g. variation in depth or width of the deck.
- 2.5.2 Piers and portals: They are specifically sensitive with regard to aesthetics. Cross sections of piers and portals are therefore often controlled by aesthetic considerations and not by structural demands. Pier need frequently to be widened towards the top in transverse direction to achieve a smooth interface with the deck.
- 2.6 Concrete: As explained below concrete is worldwide the predominant material for construction of bridges. The beauty of concrete is that it can be built to almost any shape due to its moulding characteristics. Hence it is a very good material to smoothen out transitions as mentioned above and it allows incorporation of architectural features into external surfaces of for example piers and parapets.

3. Impact during construction

- 3.1 General: Construction of a bridge or viaduct is not a matter of days but a matter of 2 to 3 years. Construction happens along existing road corridors, which are generally jammed by cars and people. Hence it is imperative to select structural concepts, which allow to move as much of the construction activity off site. Concrete is worldwide the predominant material for construction of bridges due to fact that main components are almost always locally available and maintenance is minimum if design, detailing and construction are correctly carried out. Technologies are already available, whereby the entire deck of a bridge is made from precast segments, which span over the full width of the deck and are held together with longitudinal prestressing tendons. This eliminates need for any false work and removes almost completely need for casting of concrete on site.
- 3.2 Deck construction: Even so the concept of moving as much work off site by using precast segmental technology is understood by owners, consultants and contractors, the potential this technology has with regard to shortening construction time and reducing negative impact during construction on people commuting and living along the bridges being constructed, is often not exploited. Reasons for this situation are:
- 3.2.1 The design and detailing of the deck is done without consideration of construction aspects. In order to be able to do that, designer needs to have in depth understanding on how segments of precast segmental viaducts are being produced and erected.
- 3.2.2 Contractual arrangements are not adapted for this technology: Precasting is all about standardization and mass production under factory conditions. As mentioned above the designer needs to have in depth understanding on how segments are being produced and erected. Therefore often owner goes

for design/build type contracts. This may be fine if design and construction of an entire network is given to one contractor, but has more disadvantages than advantages when design and construction is broken down into several contracts, as it is normally the case. The owner of a network ends then up with different structural details with regard to bearings, joints, drainage systems etc. making the maintenance a nightmare both with regard to management and costs. So engagement of an experienced and reputed consultant directly by the owner to carry out design/detailing for a standardized deck, which is used for the entire network, appears to be a more sensible approach.

- 3.3 Piers: Piers can like decks be made up of precast segments, which are joined together by vertical prestressing tendons.
- 3.4 Foundation: Foundation schemes are preferred, which have limited dimensions in transverse direction, since viaducts are often going along central dividers of existing at grade roads.
- 3.5 The future: The industry is far from utilizing the full potential of bridge decks made up completely from match cast precast segments. A new mind set at owner and consultant side is required to improve the situation.

4. Carbon footprint

- 4.1 General: we need to differentiate between carbon footprint during construction and carbon foot print during operational phase of a bridge.

4.2 Construction:

- 4.2.1 Carbon foot print can be reduced in construction by selecting materials, which have a small carbon foot print during manufacturing, reducing need for transport of material and cutting down on energy consumption during construction.
- 4.2.2 To reduce carbon footprint for concrete bridges is to prestress the concrete, since this allows to reduce average concrete consumption per m² deck and to reduce steel consumption.
- 4.2.3 Precasting deck and may be even piers requires standardization to allow mass production of big part of the bridge under factory conditions. This will help to lower carbon footprint, since mass production under factory conditions is more energy efficient than craftsman type production on site.

4.3 Operational phase:

- 4.3.1 Reduction in carbon footprint during operational phase is achieved by reducing need for maintenance of the bridge. Main structural elements of bridges in prestressed concrete, if correctly designed, detailed and built, require minimum maintenance. However that is not true with regard to bearings and joints. Therefore bridges should be designed as much as technically feasible and sensible with deck continuity over several spans and with frame action, since such structural systems are characterized by minimum number of bearings and expansions joints.

- 4.4 The future: Designs need to become sharper to minimize quantities of permanent work material and need to go as much as technically feasible and sensible for deck continuity and frame action.

5. Conclusion

- 5.1 The title of this paper may have created expectations that the future of bridges will all be about new bridge concepts. Of course nobody is able to predict the future. The author's opinion is however, that "conventional"

bridges still have a place in the future to improve physical mobility in cities, even so upgrading of capacity of transport corridors will have to go more underground. The predominant material for the decks of the bridges will probably remain prestressed concrete due to its high local content, its moulding characteristics and its relatively overall low carbon footprint during construction and operation phase. However major changes to mindsets of owners and designers building bridges in concrete in urban environments have to take place to fully exploit the potential inherent in prestressed concrete and in particular in precast segmental prestressed concrete. Owners have to choose suitable contractual models and designers need to have a holistic approach going well beyond structural integrity checks only but considering as much aesthetic aspects, constructability, material consumption and future maintenance demands (ref 1).

References

1. Max Meyer, "State of the art bridge construction - the challenge to choose the right method", IABSE Symposium BKK 2009.

THE PRIME MINISTER INAUGURATED the longest bridge in Assam in May 2017 and named it after Assam's cultural icon Bhupen Hazarika, musician and film-maker.

The DholaSadiya bridge spanning 9.15 km across the Brahmaputra, connects Dhola in Arunachal Pradesh to Sadiya in Assam. It has been built at a cost of Rs 2,056 crore, over the Lohit River, a tributary of the Brahmaputra, at the eastern most tip of Assam. The bridge is 3.55 km longer than the sea link over the Mahim Bay in Mumbai. The project was started in 2011. It reduces the travel time of people on either bank of river Lohit by 6 to 8 hours and saves fuel costs worth several lakhs per day in the region.

It has strategic significance as it's near Anini, 100 km from the China border. It is designed to support the weight of a 60-tonne battle tank. The bridge also features 182 piers with 'seismic buffers' - conical rods placed below the bridge that will help prevent damage in case of an earthquake.

Civil Engineering Innovation Shaping Mobility of the Future



Dr. Boris Reyher
Associate at
Schlaich Bergermann und Partner;
b.reyher@sbp.de

Prof. Dr. Mike Schlaich
Managing Director at
Schlaich Bergermann und Partner;
m.schlaich@sbp.de



Abstract: *Transportation infrastructure in the 21st century is faced with complex requirements. On the one hand, growing traffic volume worldwide puts increasing stress on existing infrastructure and requires upgrade and expansion of traffic networks. On the other hand, complex and di-verging requirements such as economic efficiency, durability, sustainability, ease and speed of construction and last not least aesthetics are posed on the design and function of bridge structures today. Schlaich Bergermann und Partner have been active in the field of bridge de-sign for the past 30 years. Several noteworthy reference projects are used to discuss the role of civil engineers in solving the challenges posed on infrastructure design elegantly. These examples feature innovative concepts such as 'integral' design for railroad and highway bridges.*

Keywords: high-speed railroad bridge, road bridge, integral design, engineering innovation, bridge aesthetics

1. Introduction

Civil engineers' work today is faced with diverse and partly contradictory requirements which challenge their technical skills and experience as well as their creativity and ingenuity. In order to arrive at convincing solutions, engineers should always pursue a holistic approach. The aesthetic qualities of infrastructure are just as important when we recognize that like any other building work, civil structures are always also part of our *Baukultur*, a cultural statement.

After German reunification, a railroad bridge design council, the *Brueckenbeirat*, was established, which consists of engineers, architects and railway professionals, and which discussed the aspects and principles of 21st century state-of-the-art railway bridge design. One result of the work of the *Brueckenbeirat* was a bridge design manual, the *Leitfaden Gestalten von Eisenbahnbruecken* [2], which aids engineers, architects and railway professionals in developing modern concepts, solutions and details for railway bridges. A selection of railroad bridge case studies designed and constructed following the principles and recommendations laid out in the *Leitfaden* are presented in the following, as well as an example for an integral highway bridge.

2. Case Study: Gaensebachtal Railway Viaduct

Gaensebachtal is a shallow valley located between cities Halle and Erfurt and required a low two-track viaduct of 1001 metres length. The reference design following the standard German framework design foresaw a series of 4 metres deep post-tensioned single span concrete box girders supported on structural bearings at concrete piers spaced at 40 metres centres. Especially due to the low height of the viaduct above the valley floor, the reference design appeared visually dissatisfactory and inadequate.

To overcome the aesthetic problems, improve the durability and minimize the maintenance requirements for the structure, Schlaich Bergermann und Partner conceived an alternative design, which was consequently put into

practice [4]. A maximum of lightness and transparency was achieved first of all by reducing the maximum span to 25 metres, which allowed for a reduction of the depth of the deck from 4 to 2 metres. The viaduct is divided into 10 blocks, each a 112 metres long integral post-tensioned concrete structure with a twin-web T-beam cross-section supported on twin concrete columns. The longitudinal braking and acceleration forces are resisted by characteristic V-shaped bracing walls located at the centre of each block. Similar bracing walls in transverse direction are located at the ends of each block to deal with transverse centrifugal forces.



Fig.1. Deutsche Bahn’s reference design for Gaensebachtal viaduct; Schlaich Bergermann und Partner’s design concept for the same.

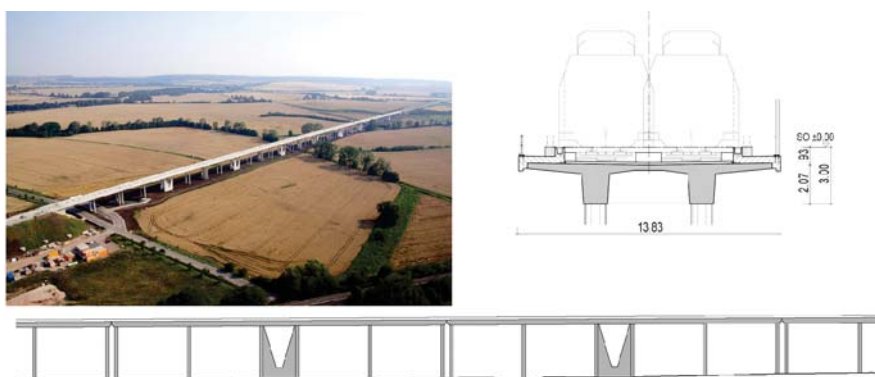


Fig.2. Completed Gaensebachtal viaduct; cross-section drawing; elevation drawing of two bridge blocks (Photo: Adam Hoernig Baugesellschaft).

3. Case Study: Grubental Railway Bridge

Grubental is a short but rather deep valley located in the Thuringian mountains which required a 215 metres long bridge to cross. Deutsche Bahn’s reference design consisted of a concrete arch bridge with 60 metres in the main span, flanked by two independent girder bridges on concrete piers. The bridge deck was to be supported on structural bearings throughout. Schlaich Bergermann und Partner’s alternative design [5] foresaw a concrete arch which fuses with the deck girder at midspan, creating a seamless and elegant structure. Next to the arch, slender integral concrete columns support the deck. Bearings are only used at the abutments, which is why the bridge can be referred to as a ‘semi-integral’ structure.

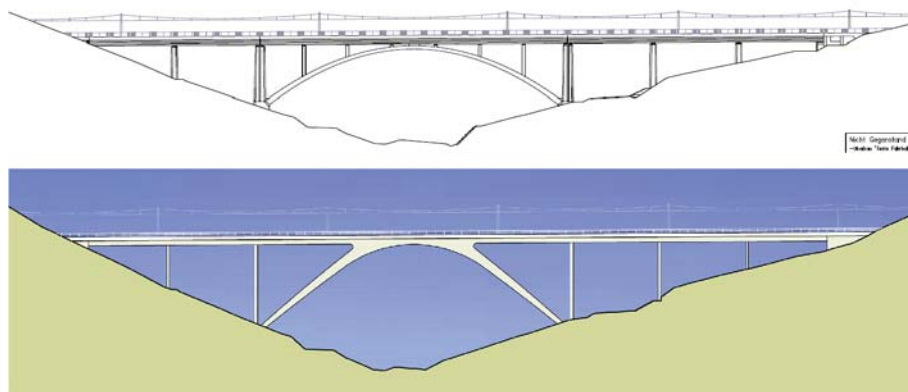


Fig.3. Deutsche Bahn's reference design for Grubental bridge; Schlaich Bergermann und Partner's alternative design concept.

The strut-like arch with its distinctive crown allows almost identical continuous spans of the superstructure, a twin-web T-beam with longitudinal and transverse post-tensioning. The tapered slender pier walls are designed to absorb the deformations due to temperature changes and shrinkage without bearings.

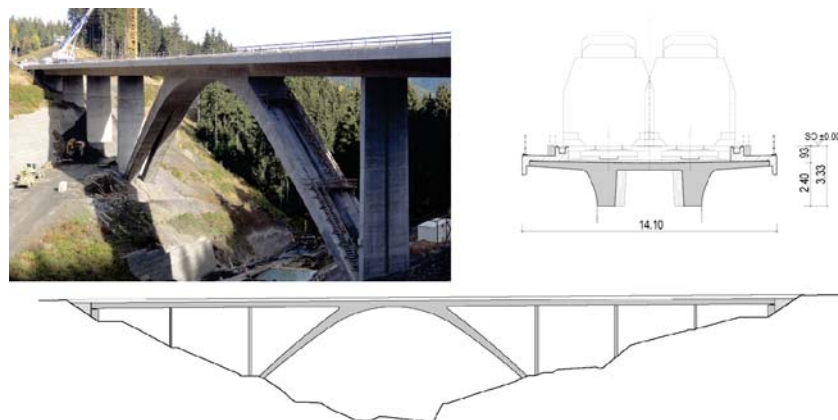


Fig.4. Completed Grubental Bridge; cross-section and elevation drawings.

4. Case Study: A11 Highway Viaduct, Belgium

The final case study deals with a four-lane highway viaduct in Belgium. The A11 motorway near Zeebrugge crosses a railroad and a shipping canal, requiring it to rise to 16 metres above the flat landscape. The reference design by the Owner foresaw a series of conventional continuous post-tensioned concrete girders supported on bearings for the dual carriageway structure. Schlaich Bergermann und Partner's alternative design for the 770 metres long major bridge foresees a slender concrete deck supported on integral pier walls



Fig.5. Construction of A11 highway bridge (Photo: Jan de Nul Group).

at 34 metres centres. Only at the extreme two pier axis at either end, the structure relies on bearings to deal with the large temperature movements.

5. Conclusions

Several case studies of integral and semi-integral railroad and highway bridges clearly demonstrate the advantages and potential of this innovative construction principle.

- The slender structural elements increase the elegance and transparency of the structure.
- Bearings and joints are largely omitted resulting in a reliable, robust and low-maintenance structure.
- Shorter spans allow solid cross-sections for the superstructure such as T-beams. Continuous girders without movement joints increase the efficiency of the superstructure in terms of its rigidity and damping behaviour.
- Slender integral piers with solid cross-section are more efficient to construct than the standard hollow box piers.

The integral method will prevail in many areas of railroad and highway bridge construction due to the favourable behavior of the structures, their efficiency, their economy, and their sustainable, holistic and aesthetic qualities.

References

1. M. Schlaich, “Integral Railway Bridges - New Bridges in Germany”, ICI-IWC Conference, Hyderabad, 2013.
2. J. Schlaich, V. Schmitt, S. Marx et.al.: “Leitfaden Gestalten von Eisenbahnbrücken”, DB Netze AG, Berlin, (2008).
3. M. Schenkel: “Verkehrsprojekt Deutsche Einheit (VDE 8.2): Eisenbahn- Neubaustrecke Erfurt-Leipzig/Halle – Herausragende aktuelle Baumaßnahmen”, VDI-Bautechnik Jahresausgabe 2010/2011, pp. 41-51.
4. M. Schenkel, A. Goldack, J. Schlaich, S. Kraft: “Die Gänsebachtalbrücke, eine integrale Talbrücke der DB AG auf der Neubaustrecke Erfurt-Leipzig/Halle”, Beton- und Stahlbetonbau 105 (2010), Vol. 9, Ernst & Sohn Verlag, pp. 590-598.
5. A. Keil, P. Wenger, T. Fackler, J. Schilling: “Die semiintegrale Grubentalbrücke – Besonderheiten bei der Planung”, Bautechnik 88 (2011), Vol. 10, Ernst & Sohn Verlag, pp. 723-730.

HAVING TRIAL-LAUNCHED INDIA'S FIRST ELECTRIC BUS in February 2014, the Bangalore Metropolitan Transport Corporation (BMTC) board, has finally given its in-principle clearance to induct 150 electric buses.

With this, Bengaluru is likely to be the first city in the country to launch city bus transport operations using such a large fleet of electric buses. Whilst the capital cost is high, the electric buses are pollution-free and the maintenance and mechanical costs involved in operating these buses is very low compared to that of petro-diesel vehicles.

Unique Engineering Features of Delhi Metro



Dr. Mangu Singh
*Managing Director, Delhi Metro rail Corporation (DMRC),
 mdmetro@hotmail.com*

Abstract: *There was no experience of constructing a modern metro in the country. The only experience was the construction of the Kolkata Metro North-South Line which took 24 years to complete a 16.5 km Line. Therefore, many innovating engineering solutions were adopted in developing the metro system in Delhi to ensure speedy construction and safety of public and property during construction with least negative impact on environment. Further in order to have financial sustainability of the system, energy efficient, cost effective solutions were deployed.*

Introduction

Though the need for a rail based public transport system for the city of Delhi was felt long back but it was only in mid 90's when Phase I of Delhi Metro Project was sanctioned by the Government. The responsibility of construction of the rail based mass transport system was entrusted to Delhi Metro Rail Corporation Ltd., a Special Purpose Vehicle, formed for this purpose. The Phase-I of the project was sanctioned by the Government in Year 1995, however, the actual planning and execution of work were started only in 1997 when Delhi Metro Rail Corporation came into real existence. Phase-I of the project consisting of 3 Lines, totalling about 69 km, was completed in 2005 i.e. in about 7 years 3 months time which was 2 year 9 months before the original programme of revenue opening date. The first Section of a small length of about 8 km, however, was opened in December 2002.

Phase II of the project consisting of about 125 km was mostly completed by October 2010, before the Common Wealth Games were held in October 2010 in Delhi. Phase II was also completed within time and cost. That included the Airport Express Line of about 22.5 km executed on a PPP basis. After completion of Phase-II, a network of about 190 km became operational.

Phase-III of about 140 km is under implementation and is likely to be completed by December 2017. Three small sections of Phase III, totalling about 22 km have already been made Operational.

When planning of construction of Metro System in Delhi was started in 1997, the biggest challenge was to decide on the system parameters. At that time the experience of modern Metro system within the country was very limited. A Line of 16.45 km was only operational in city of Kolkata which was constructed between 1974-1996. This Line was constructed with vintage type of technology available at that time. Therefore, that experience was not of any help for deciding the technology system for the proposed Delhi Metro.

Delhi had a peculiar characteristic of very heavy traffic demand on the selected Corridor. Delhi also has difficult climatic conditions ranging from extreme hot, dry and dusty summer to very cold winters and stormy rainy seasons. Internationally also by that time, not many Metros had experience of similar climatic and traffic conditions. Therefore, while deciding on technical parameters and systems, these issues were required to be taken into account. Further, the city roads being very congested could not have afforded to yield land for occupation for

construction of Metro for long duration. The City also did not have any experience of tunnelling in a very difficult and variable geology ranging from soft silty clay to weathered fractured rock to very hard quartzite rock. The construction methodology, technology and procedures were therefore, required to be selected to suit the requirement of speedy construction.

Construction of Underground Tunnels:

Tunnels for Metro System are typically shallow with minimum over burden as deeper tunnels would necessitate deeper stations, inconvenience for Metro users and also energy inefficient station with deeper escalators and lifts. Shallow tunnelling in urban area poses difficulties of settlement control at surface to protect structures properties, life, traffic and utilities. In Delhi specially designed Shield Tunnel Boring Machines with tailor made specifications, to suit the geo-technical conditions have been deployed. The Condition Survey of structures in the influence zone of tunnelling was carried out and the effect of projected settlement on the buildings/ structures was examined in advance to ensure that the tunnelling would be done safely without causing damage to the structures. Suitable modifications to the design were done based on the pre-condition survey and settlement analysis.

Pre-cast concrete segmental lining are used for tunnelling. The segment casting yards were located away from the busy central urban area. The segments are transported during night hours in large trailers to avoid traffic congestion during day time/ peak hours. Similarly, batching plants for concreting works were also located outside the main urban area.

Since at most of the locations, tunnelling was below the ground water table, hydrophilic gaskets were used to prevent leakage from the segment joints. A large number of tunnel boring machines were deployed so that completion of tunnels matched with the completion of station structures and optimum project completion period was achieved. With that, for Delhi, the project completion of underground sections was 4 ½ to 5 years'time, starting from the bid process to finally opening of the line after necessary trials was achieved.

Station Construction:

The underground stations are mostly located below major roads and, therefore, occupation of roads for construction of stations became very critical. Occupation of roads for longer duration would cause inconvenience to the public as traffic is required to be diverted partially or fully. Therefore, top down method of construction was adopted using cut & cover construction method.

RCC diaphragm walls were first constructed with highest level of quality. This was possible due to advancement in diaphragm wall construction technology. Verticality of diaphragm wall panels was ensured by suitable trenching method and confirming trench verticality before reinforcement was lowered and concreting done. The verticality was checked by recording the trench profile by special equipment like "Codan" and in case the trenching was not vertical to the expected level, the trench was refilled and re-trenching done. In order to prevent collapse of soil into the trench, special polymer slurry was used instead of bentonite to avoid the problem of disposal of environmentally hazardous bentonite slurry. Similarly, it has been possible to provide PVC water stops between the two diaphragm wall panels to prevent the leakage from the diaphragm wall joints. Once the diaphragm wall was completed along the perimeter of the station, the top slab of the station box was first completed in part or in one go as the case may be, leaving opening in the top slab for further excavation and construction of the structures below the top slab. With this, it was possible to restore the roads for public quickly and reduce the road occupation time drastically.

Elevated Viaduct:

The use of segmental construction in elevated viaduct/ bridges was not common in India till DMRC started metro construction in Delhi. The construction of elevated viaducts in city areas if done with the conventional cast-in-situ method would cause great inconvenience as that would need occupation of roads. Further it would take much longer duration to complete the viaduct works. DMRC, therefore, decided to go in for segmental construction in big way.

The other advantages of segmental construction are:-

- Segmental construction is a cost effective method for a vast range of spans and types of structures. Structures with sharp curves and variable super elevation can be adjusted to suit the requirements. Segmental construction allows the reduction of construction period as segments are manufactured and assembled rapidly thereafter whilst substructure work is in progress.
- Segmental construction shields the environment as minimum space is required for foundation and substructure at site. The superstructure is manufactured at a place away from busy locations. Placement of superstructure is completed with the system erected from piers at heights.
- In case the site situation demands, then it is easy to adjust last minute changes in the span configuration.
- It is easier to ship smaller segments by road trailers on the city roads.
- During construction, the intervention to the road traffic is considerably reduced.
- Segmental construction results in aesthetically pleasing structures and good finishes.
- Significant improvement in quality is possible in the casting yard.
- During construction, the technique exhibits high record of safety.

Use of precast full span U girders

Use of precast full U girders not only speeded up the construction but also improved the aesthetics of the viaduct because of sleek shape and uniform quality.

Precast pier caps and pre-cast full span U girders are suitable for constructing long elevated viaducts for railway system.

Key advantages of the system

- Integrated sound barrier
- Integrated cable support and system functions
- The longitudinal profile of the track could be lowered by 1.5 to 2 meters compared to regular design.
- Integration of the walkway for upkeep and passenger evacuation on each side of the tracks.
- Cost effective from both structural and system point of view.
- Flexibility of construction starting points along the line.

The viaducts viz. Airport Metro Express Line, Faridabad Metro Line, Noida-Greater Noida Metro Rail Line and Kochi/ Lucknow Metro Rail Line use full-length double precast U girders.

Use of special structural forms like Extradosed bridge

Extra-dosed bridges are the best structural solution in places where long spans are required to be constructed and there is space constraint. They are also more economical than the cable stayed bridges. The pylon heights in extradosed bridges are almost half the height as compared to cable stayed bridges.

For the extension of the U shaped viaduct of line-3 of Delhi Metro, DMRC dealt with the crossing of five railway tracks with numbers of constraints, sharp plan curvature, railway vertical clearance, difficult locations of intermediate piers and unavoidable interruption of the railway traffic. Besides technical difficulties, the line opening date was scheduled within less than one year.

The Pragati Maidan bridge is an extradosed railway bridge with a main span of 93m. The deck cross-section has a U shape, which allows a great integration of the metro system in the supserstructure. The extradosed cables are wrapped by a concrete beam that allows to consider them as internal prestressing. This beam also enhances the stiffness of the main span.

The extradosed bridge involved a very complicated construction technique as it had to be constructed over five very busy lines of the Indian Railways. With almost 200 trains, comprising many key trains going towards western and eastern India and passing on the tracks under the new bridge day in and day out, it had to be constructed without any interruption to the train traffic. Besides the first bridge in Japan, this was the second bridge of its kind built over a railway crossing.

It is the first extradosed bridge ever built in India to be erected using the cantilever construction technique.

Selection of Rolling Stock

For a public transport system like metro, financial sustainability of the system depends on keeping the cost of operation and maintenance low. The cost of energy normally constitute around 30-40 percent of the operational cost. It was, therefore, necessary to have a very energy efficient system.

DMRC has successfully deployed highly energy efficient metro rolling stock with very high reliability, maintainability and safety standards. Stainless steel car body has been chosen to achieve light weight and less maintenance on account of corrosion. All materials used in the stock are of very high fire rating. Propulsion equipment design has been chosen to achieve high acceleration coupled with highest possible regeneration of energy during braking. Passenger comfort has been kept in focus and the design incorporates two level suspension systems with superior bogie design for improved ride quality. State of the art passenger announcement systems and passenger information system coupled with dynamic route map provide requisite information to commuters. High capacity, energy efficient, on board air conditioners have been provided. Car body construction ensures excellent thermal and acoustic insulation to achieve interior conditions consistent with the requisite international standards. To improve the rail wheel interaction and for mitigation of noise and wheel wear, wheel flange lubricators are used with bogie design suitable for negotiation of sharp curves. Braking characteristics are designed for full regenerative braking over almost the complete range of operation and apart from improvement in energy consumption this would help in reduction in friction braking requirements. DMRC is committed to achieve maximum indigenization and have achieved notable success and almost 90% of the stock deployed in DMRC has been manufactured in India. By adopting regenerating type of rolling stock technology, DMRC become the first organization in the world to have registered CDM Project with UNFCC in the rail based transport sector and has earned carbon credit.

25 kV AC Traction System

Till the Delhi Metro project most of the metro systems in the world were seen to have DC traction system, mostly around 750 Volts with 3rd rail current collection system. The low voltage DC system has limitations on the capacity of the system and, therefore, some metros started using 1500 Volts DC system with overhead catenary. A higher voltage is necessary for higher line capacity as more numbers of trains are required between 2 Sub-Stations, thus drawing very high current. Since the Delhi Metro required a very high capacity ranging from 60,000 passengers per hour per direction to 90,000 passengers per hour per direction, explored the possibility of further high voltage and finally selected 25 kV AC traction system which is very common for main line operation throughout the world. Therefore, for the first time for metro type of operation, 25 kV AC traction system was adopted in Delhi Metro and since then the system is working very satisfactorily. The light weight efficient rolling coupled with high voltage AC traction system has proved to be very energy efficient system and helped Delhi Metro Rail Corporation in maintaining its financial viability.

Automatic Fare Collection System

It was also realized that having an efficient metro network necessarily required a passenger friendly, state-of-the-art fare collection system.

The Automatic Fare Collection System has lesser requirement of staff, lesser possibility of leakage, amenable to quick fare changes, all transactions are logged and management information reports easily generated. Hence, the obvious choice between the manual and the automatic system was the Automatic Fare Collection System (AFC).

Again the choice was between a magnetic recyclable ticket/contact media or a contactless media. The analysis done by DMRC lead to the conclusion that contactless solution is the optimum solution as it provides better through put, more number of recycling of the ticketing media and less prone to mechanical problem due to contactless interaction between the validator and the ticket. Contactless smart media cards were considered ideal for multi journey but the single journey dilemma remained on cost considerations. Finally, CST's were found to be the right choice for single journeys. The single journey token themselves are initially more expensive to produce, but they are recovered at gate exits and can be reused up to 50,000 times, reducing the unit cost per journey.

DMRC was the first metro system in the world to introduce this type of contactless smart token for single journeys. Today, however many metro systems in the world have adopted this system.

Conclusion:

The number of unique engineering features adopted in Delhi Metro has helped in developing the metro system at a very rapid pace to provide relief to commuters in Delhi NCR from severe congestion on roads. DMRC is providing safe, comfortable and very reliable transport system to the city of Delhi and the NCR. The trains are running at more than 99.7% punctuality. With the application of energy efficient technology, the economical benefits from the project are estimated in the range of 20-25%. The system has also helped in reducing the carbon dioxide emission and resulting reduction in pollution level in Delhi and NCR.

Past Practice & Recent Developments in Seismic Design of Transportation Structures (Bridges) as Per Indian Standards



Mr. Alok Bhowmick
 Managing Director, B&S Engineering Consultants Pvt. Ltd., Delhi
 bsec.ab@gmail.com

Abstract: Evolution of seismic design provisions in Indian Standards over the last fifty years have been reviewed in this paper with an emphasis to the estimation of design seismic force. BIS code (IS 1893), Indian Road Congress (IRC) standard for highway bridges and RDSO Guidelines for railway bridges are compared. Design parameters for comparison include the zone factor/ peak ground acceleration, importance factor, local soil condition, design spectra and response reduction factor. The paper also highlights the ongoing work being carried out by the IRC and BIS code committees in further improving the seismic provisions of the code. Recent changes adopted in the seismic design of railway bridges are also compared with the requirement for similar road bridges.

Introduction

Based on geological and tectonic setting, Indian subcontinent is divided into three distinct parts, namely, the Himalayan region, the Indo-Gangetic Plain and the Peninsular India. While the seismic catalog is available reporting the past seismic events triggered in Indian continent, the database is neither rich nor reliable before the 18th century. **Table 1** presents some of the major events and one may count seven events greater than magnitude 8 in last 200 years. This statistics is enough, perhaps in a loose sense, to argue about the strong seismicity of Indian subcontinent. Over the years, dissemination of research output at the national and international levels, and increasing awareness of socio-economic loss in some of the major events triggered in the Indian subcontinent and elsewhere, have resulted in upgrading the guidelines and standards for seismic design. Two essential components of the state of the art seismic design are the estimation of seismic hazard consistent with the design life and socio-economic importance of structure and its design against multiple performance objectives. Indian seismic design codes have not yet reached the international standard. This paper is aimed to discuss the evolution of seismic design provisions in Indian standards, especially, that related to the bridges.

The Bureau of Indian Standards (BIS) code on earthquake design, IS 1893, provides general seismic design requirements and guidelines, whereas other standards are also available and enforced in the seismic design of bridges, for example, standards published from Indian Road Congress (IRC-6) and Indian Railways (IRS Bridge Rules). IS 1893 was first published in 1962 and subsequently revised in 1966, 1970, 1975, 1984, 2002 and 2016. In its fifth revision, IS 1893 was split into five parts, and to date, only four parts have been published (namely Part-1⁽¹⁾, Part-2, Part-3 and Part-4). The part dealing with dams and embankments is yet to be revised. Meanwhile IS 1893 (Part-1) has undergone one more revision and the sixth revision has just been published. The first IRC Bridge code (i.e. IRC: 6) was published in December, 1958⁽²⁾ and reprinted in 1962, and 1963. The second revision of IRC:6 (1964 edition)⁽³⁾ included all the amendments, additions and alterations made by the Bridges Specifications and Standards (BSS) Committee. Third revision of the Code (in metric units) was published in 1966⁽⁴⁾. Though a number of amendments were introduced in between, it took nearly 34 years to bring out the fourth revision in the year 2000. The Fifth revision of the Code was published in the year 2010⁽⁵⁾ and the revised

edition of the Code, in its present form, was brought out in the year 2014⁽⁶⁾. The seventh revision of the code is scheduled to be published in July 2017.

The first publication of 'Bridge Rules' specifying the design seismic load for railway bridges was published by Indian Railways in the year 1941⁽⁷⁾. This was revised in 1964 and subsequently 48 correction slips have been issued by RDSO till date. IITK-RDSO jointly published a guideline on seismic design of Railway Bridges in November 2010⁽⁸⁾. Indian Railways felt the need for bringing out a guideline which can substitute the outdated IS:1893-1984⁽⁹⁾ for bridges and therefore came out with this guideline in the interim. This guideline was recently revised by RDSO (January, 2015). There are considerable differences in the provisions of this new RDSO guideline for Railway Bridges and those in IS:1893 (Part 3) published by BIS.

This paper first briefly discusses the evolution of IS 1893 over the years. Next, evolution of seismic design provisions in standards exclusively for bridges is summarized. Finally, the paper concludes with the issues currently under discussion and expected to appear in next revision of the standards.

Evolution of Indian Standard IS 1893

IS 1893, 'Recommendations for Earthquake Resistant Design of Structures', was first released in 1962 and revised for the first time in 1966. The entire country was then divided into seven Seismic Zones (0 to VI); the associated maps are presented in Figure 1 (a and b). Seismic zoning was based on the isoseismals of the past earthquakes. Intensity measured in MMI scale less than or equal to V was assigned to Zone 0; VI to 1; and so on. The Koyna region, which at that time was located in Zone 1, experienced an M6.5 earthquake with maximum shaking intensity VIII in MMI scale. This incident brought out a significant revision of seismic zone map that was included in IS 1893 in 1970. In this revision, Zone 0 was merged with Zone-I while Zone-VI was merged with Zone-V (Figure 1c). The 1970 revision of IS 1893 presented a more rational approach for design of buildings and substructures of bridges. The third revision of the standard was brought out in 1975 with a few changes including, a) zone factors on a more rational basis; b) importance factors; c) building's flexibility in design force calculation; d) modal combination rule; and e) new clauses for hydro-dynamic force. Clauses on concrete and masonry dams were also modified. Based on the experience gained in 14 years, the fourth revision was published in 1984. The revision included the concept of performance factor depending on the structural framing system and on the ductility of construction for buildings, even though the performance factor was not introduced for other structures such as bridges and water tanks.

The 1993 Latur earthquake (M6.4 with maximum intensity IX in MMI scale) occurred in Zone I and thereby requiring significant revision of the seismic zoning map. The Fifth revision of IS 1893 was brought out in 2002 and it was decided to split the standard into five parts in order to enable more frequent changes in the code. Part 1 contains provisions that are general in nature and applicable to all structures. It also contains provisions that are specific to buildings only. Part 2 presents the requirements related to the liquid retaining tanks both types, namely, elevated and ground supported. Part 3 is to discuss the requirements related to the bridges and retaining walls. Seismic resilience of industrial and stack like structures are addressed in Part 4. Part 5 is considered for dams and embankments. Unless stated otherwise, the provisions in Parts 2 to 5 should be read necessarily in conjunction with the general provisions in Part 1. Further, pending finalization of Parts 2 to 5 of IS 1893, provisions of Part 1 would be read along with the relevant clauses of IS 1893: 1984 for structures other than buildings. The following are the major and important modifications made in the fifth revision released in 2002: a) The Seismic Zone map is revised with only four zones, instead of five (Figure 1d). Erstwhile Zone I has been merged to Zone II, b) Seismic Zone Factors have been changed with more realistic values of effective peak ground acceleration considering Maximum Considered Earthquake (MCE) in each seismic zone, c) Response Spectra are now

specified for three types of founding strata, namely rock and hard soil, medium soil and soft soil, d) Empirical expression for estimating the Fundamental Natural Period of multi-storeyed buildings has been revised, e) The 'Response Reduction Factor' is included in place of the earlier performance factor, f) Design Base Shear is restricted to a minimum through empirically specifying the natural period, g) The Soil-Foundation System Factor is dropped by restricting the differential settlements in severe seismic zones, and h) Provision of Torsional Eccentricity has been modified.

Summary of IS 1893 Provisions for Bridges

A brief comparison of the seismic design provisions of bridges specified in IS 1893 (Part3)-2014⁽¹⁴⁾ and 1984 version of the IS 1893 is present below.

Scope of the work and Seismic Zoning

1984 version did not elaborate the scope and addressed five seismic zones (I-V). Horizontal seismic coefficients recommended were 0.01, 0.02, 0.04, 0.05 and 0.08 for the Zones I-V, respectively. Recent version presents a well-defined scope that includes highways, railways, pedestrian bridges and aqueducts. Zone I and II are clubbed and Zone Factors are specified as 0.10, 0.16, 0.24 and 0.36 for Zones II –V, respectively.

Applicability

1984 version recommends that i) Slab, pipe and box culverts need not be designed for seismic forces in any seismic zone; ii) Masonry and plain concrete arch bridges with span more than 10m shall not be built in Zone IV and Zone V; iii) Bridges of total length not more than 60m and individual span not more than 15m need not be designed for earthquake forces, other than in Zone IV and V. Recent version introduces following additional points: i) Concept of 'Regular' Bridges and 'Special and Irregular' Bridges; ii) Site specific spectra for bridges with span greater than 150m and for special bridges (where soil conditions are poor) in Seismic Zone IV and V.

Method of Analysis

The 1984 version provided two analysis methods, namely, Seismic Coefficient Method and Response Spectrum Analysis. Parameters involved in the estimation of design seismic force includes Basic Seismic Coefficient (α_o), Seismic Zone Factor (F_o), Importance Factor (I), and Soil-Foundation Factor (β). Response Spectrum Analysis was recommended only for bridges with complex geometry such as, suspension bridge, Bascule bridge, cable stayed bridge, horizontally curved girder bridge and reinforced concrete arch or steel arch bridge. Response spectrum analysis was also required for bridges with pier height more than 30m and span length more than 120m. **Table 2** presents the recommended values for Soil-Foundation Factor. The recent version recommends two additional methods of analysis, namely, time history and pushover. Further, the Soil-Foundation Factor is dropped and the effect of soil is accounted for in the Design Response Spectrum. Detailed dynamic studies are envisaged for all special and major bridges. Empirical formula for calculating natural period is revised. Importance Factor remains the same whereas Response Reduction Factor is introduced. Effect of damping was also included in the Design Response Spectrum (for example, 2%, 5% and 10% of critical) in 2002, but deleted in 2016 version. The Design Spectrum with 5% damping is to be used for all materials as per the recent code. Capacity design principle is recommended for the design of connection, substructure and foundation.

Live Load Consideration

The 1984 version recommended 50% live load for seismic load calculation in case of railway bridges and 25% for highway bridges. However, gravity load calculation should include 100% live load regardless of the case.

Recent version considers 20% live load for the highway bridges and no live load for the bridges on rural roads, and 30% live load for railway bridges without impact.

Vertical Seismic Force

Both versions recommend consideration of vertical seismic force in Zone –IV and V. The 1984 version specified a Seismic Coefficient which is half of that for the horizontal ground motion. In other words, the Design Spectra for the vertical ground motion is half of that for the horizontal ground motion. This factor is modified to 0.67 in the 2002 version, which also imposes a separate calculation of natural time period specific to the vertical vibration.

Ductility and Overstrength

The 1984 version did not account for the ductility and overstrength in the seismic design of bridges. Recent version has brought out these explicitly by introducing the Response Reduction Factor, ‘R’. Different R- factors have been proposed for different components of the bridge, depending upon the redundancy, expected ductility and over-strength in them. The ‘R’ factor is recommended to be ‘1’ for the design of foundation and 0.8 for the design of bearing.

Directional Combination

Simultaneous application of vertical and uni-directional horizontal seismic force was recommended in the 1984 version of the code whereas, recent version recommends the 100-30-30 rule for directional combination, in which, 100% seismic force in any particular direction is to be considered simultaneously with 30% of seismic force in other two orthogonal direction.

Seismic Detailing

No special detailing for seismic loading was recommended in the 1984 version whereas the recent version includes the followings: i) Provision for anti-dislodging of girders; ii) Use of vertical holding down device, stoppers, restrainers and horizontal linkage elements and iii) Provisions for minimum seating width of superstructure over substructure.

Earth Pressure

Only cohesion-less soil was considered in the 1984 version, which is extended to incorporate C- \hat{O} soil in the recent version.

Development of Seismic Provisions in IRC Code

First IRC Bridge Code IRC:6-1958 (Section-II)

The first IRC Bridge Code covering seismic provisions was published in the year 1958. The outline of the first draft was originally published in 1946 in the form of a paper⁽¹⁰⁾ and the paper was discussed at the Indian Roads Congress session at Jaipur held in 1946. Clause 222 of this code pertained to ‘Seismic Force’ and the Zone Map as shown in Figure 2 was introduced. The subcontinent was divided into three seismic zones based on expected seismic intensity or degree of damage, namely, *liable to minor damage or nil*, *liable to moderate damage* and *liable to severe damage*. The code did not enforce seismic design in the first zone whereas, recommended a design seismic force as 5% and 10% of the seismic weight (dead load and (full) live load) in the second and third zones, respectively. Also identified is a set of isolated pockets (clause 222.3), namely, the Epicentral Tracts, wherein the design seismic force was left to the discretion of the structural designer. Note that there was a sense

of deciding the site-specific design force in epicentral track and this may be considered as a precursor of the site-specific Seismic Hazard / Spectra. Clause 222.4 recommended the direction of seismic force to be such that maximized the resultant stresses in the member under consideration. This may be considered as the first step of accounting for the directional combination, such as 100-30 rule. Further, seismic and wind forces were not recommended to be considered simultaneously. Another important recommendation specified in this early version of IRC code was not to reduce the seismic force on account of the buoyancy, which recognized that seismic force depends on mass (and not weight) of the element. Nevertheless, effect of flexibility of structure is not identified in seismic design.

Second and Third Revisions of IRC: 6 -1964 & 1966

The Second and Third revisions of the IRC: 6 were published in the years 1964 and 1966, respectively. There was no modification in seismic provisions in these revisions of the code (except for change in unit system from FPS to Metric) and the same regional seismic map of 1958 was continued. Recall that IS 1893 was released in 1962 and revised first time in 1966. Associated seismic zone maps, as presented in Figures 1a and 1b, may be compared with that of IRC (Figure 2). Note the seven seismic zones in IS 1893 against three zones in IRC code. Clearly, the IRC code committee did not take cognizance of work on seismic zone map over the years. In 1979, the Seismic Zoning map of IS: 1893 was introduced for the first time in the foundation code IRC:78-1980⁽¹¹⁾. This was later reproduced in IRC: 6 in the September 1981 reprint. Apart from zone map, also adopted are the Importance Factor, Soil-Foundation Coefficient, etc. For example, Horizontal Seismic Coefficients recommended were 0.01, 0.02, 0.04, 0.05 and 0.08 for the Zone I-V, respectively. **Table 2** presents the factor adopted to account for the variability in soil-foundation systems. Importance Factor was considered as 1.5 for important bridges and 1.0 for all other cases.

Fourth Revision of IRC:6 -2000 and Amendment in 2003

There was no modification in seismic provision in this revision of the code, when it was first published in the year 2000. However, after the Bhuj Earthquake in January, 2001 followed by the publication of IS:1893 (Part-1) – 2002 with significant upward revision in the seismic provisions, the IRC code was revised and upgraded in line with the BIS Code. Broadly, the major changes made in the Seismic Clause, introduced in 2003 as Interim Provisions, as compared to the previous version of the Code were: a) The Seismic Zone Map was revised in line with IS: 1893 (Part1) – 2002 with Seismic Zone Factors (PGA) introduced, in line with BIS code [PGA(in g) of 0.1, 0.16, 0.24 and 0.36 are considered for the Zone II-V, respectively]; b) Design Force calculation was based on Spectral Acceleration, which accounted for the flexibility of the structure; c) Response Spectrum was specified for three types of founding strata (i.e. Rock or Hard Soil, Medium Soil and Soft Soil; see **Table 3** for details); d) Response Reduction Factor was introduced but assumed to be taken as 2.5 regardless of the member; e) Ductile detailing was recommended in line with the provisions of IS 13920; and f) also recommended are the provisions of Seismic stoppers, STU, Base Isolation, Seismic Fuse, etc.

Fifth Revision of IRC: 6 - 2010

Fifth Revision of IRC: 6 was brought out in the year 2010, wherein the following changes were incorporated: a) Response Reduction Factors were rationalized and made variable (ranging from 1.0 to 4.0) depending upon the type of substructure and bearings (**Table 4**); b) Criteria were outlined so as to ascertain the importance of bridges and Importance Factor was rationalized based on different categories, for example, Normal, Important and Large critical bridges, etc. (Table 5); c) Directional combination was specified through 100-30-30 rule; d) Reduced Live Load was suggested during the seismic event; and e) Provisions were made in calculation of spectral ordinate for damping other than 5%.

Sixth Revision of IRC: 6 - 2014

Consequent upon the publication of Limit State Concrete Code IRC: 112 in the year 2011, and drafting of IS: 1893 Part 3 for Bridges undertaken by BIS, there was a need to further revise the Fifth Revision of IRC: 6 based on Limit State approach and taking into account the related development in IRC: 112, which was largely influenced by the Eurocode. For example, the design philosophy of the Eurocode is to achieve (with appropriate reliability) the non-collapse requirement, under ULS and IRC decided to adopt the same philosophy and hence, required revisiting the safety margin under seismic code. The revised edition of the Code, i.e. the Sixth Revision published in January, 2014 incorporated the following amendments to the Fifth Revision of IRC: 6: a) Response Spectrum is modified in line with the IS:1893 spectra; b) Response Reduction Factors further rationalized (**Table 6**); c) Cracked Moment of Inertia is allowed for Time Period calculations in case of RCC structures considering the Limit State Design approach; d) Reference to IRC: 112 is given in place of IS: 13920 for ductile detailing; e) Seismic load for design of foundation to be taken as 1.35 (1.25) times the force transmitted by RCC (steel) substructure.

Seventh Revision of IRC: 6

The seventh revision of the code, which is likely to be on the shelf soon, incorporates modifications in the Response Reduction Factors, Partial Load Factors in Load Combinations, provision of seismic forces in the buried part of the structure, changes in Earth Pressure clause and inclusion of Fatigue Loads.

Development of Seismic Clauses in Railway Codes

First Publication of Bridge Rules: 1941⁽⁷⁾

The first Railway Code, Bridge Rules, was published in the year 1941 and the seismic provision was laid down in Clause 27:

“Seismic load need only be taken into account if the local conditions require it, and the allowance for horizontal acceleration shall depend on such local conditions but shall not exceed one-eighth of gravity. Seismic load need not be allowed for in standard designs. Wind and seismic loads shall not be assumed to act simultaneously on a structure.”

First Revision of Bridge Rules in 1964

First revision of the Bridge Rules was published in the year 1964 and seismic provisions were recommended in Clause 2.12 that had two sub-clauses.

“Sub-Clause 2.12.1: Seismic load need only be taken into account if the local conditions require it, and the allowance for horizontal acceleration shall depend on such local conditions but shall not exceed 0.12 of gravity. Seismic load need not be allowed in standard designs except in cases given in Clause 2.12.2.

Sub-Clause 2.12.2: In normal cases seismic effect need not be combined with live load; but where local conditions require it, a combination of seismic effect, live load, longitudinal forces and other co-existent forces should be taken in the design.

A Zone Map is not recommended to calculate design seismic force in both, the original and the first revision of Bridge Rules.

Incorporating Correction Slips

Bridge Rules have not been revised since 1964. However, a number of correction slips have been incorporated as interim provisions in subsequent reprints. Below is a summary of the reprints since the first revisions.

Reprinted in 1986 (Incorporating Correction Slips 1-15)

Seismic zoning map from IS:1893 was used for the first time in IRS code. Basic horizontal seismic coefficient was considered as 0.01, 0.02, 0.04, 0.05 and 0.08.

Correction Slip No 28 dated July, 2002

Seismic forces to be considered in case of bridges of overall length more than 60m or spans more than 15m in Zone I, II and III; and regardless of the span if located in Zone IV and V. It is worth noting here that while IS:1893 (Part1):2002 was published in June 2002, with significant changes in seismic zoning map and peak ground acceleration, the Railway Standards continued with the old practice of specifying seismic coefficient.

Correction Slip No 42 dated October, 2009

The number of Seismic Zones was changed from five to four conforming to IS:1893 (Part 1):2002 but Seismic Coefficient Method was continued.

Correction Slip No 44 dated February, 2014

Seismically preferred and not preferred configurations of bridge were included. It also included the provisions for vertical holding down device, horizontal linkages and minimum seating width requirements.

IITK-RDSO Guideline published in 2010⁽⁸⁾

This guideline was developed for Indian Railways at IIT Kanpur and was published in the year 2010. This was substantially different in design philosophy and in design approach as compared to the prevailing IRS code at that time. The guideline included commentary of the codal clauses as well as worked out examples. Substantive changes included: a) Seismic Zones and Response Spectrum as per IS:1893 (Part-1):2002; b) Flexibility of the Bridge depending upon Natural Period; c) Response Reduction Factor to allow for inelastic behavior; d) Directional Combination; e) Introducing detailed analysis such as Response Spectrum, Time History and Pushover; f) Assessment of liquefaction; g) Provisions for seismic isolation devices; and h) Post earthquake operations and inspection. Response Reduction Factors in this guideline was much lower as compared to the 'R' factor given in IRC: 6 prevailing at the time of publication of the document (i.e. in 2010), leading to conservative design forces. This guideline was implemented in several projects by Delhi Metro Rail Corporation (DMRC) in metro projects, subsequent to its publication in 2010.

Revised RDSO Guideline published in 2015⁽¹³⁾

RDSO has come out with the revised guideline in January, 2015 wherein the R Factors were modified, as it was felt by RDSO that the design forces on structure as per IITK-RDSO guideline were too conservative. Also the Live Load factors in load combination were changed in the amended guideline. With the issuance of this new guideline, the earlier IITK-RDSO guideline stood withdrawn. Interesting to note that, by the time the new RDSO guideline was published, IRC: 6 revised the 'R' Factors in the code by lowering the values (thereby increasing the seismic forces). Around the same time, IS:1893 (Part 3): 2014 was issued with 'R' Factors much lower than even the IITK-RDSO guidelines.

Comparison of Design Seismic Force

Two river bridges with natural periods 0.5 sec and 1 sec, located in Delhi on medium soil (Type II) are considered with an Importance Factor of 1.5. RC circular pier on well foundation is chosen in both cases. The Design Seismic Force (fraction of seismic weight) is calculated using different versions of IS 1893, different versions of

IRC codes and the railway bridge provisions, and presented in **Table 7**. It may be recalled that until recently all three bridge codes (IS code, IRC code and the RDSO provisions) did not account for flexibility of the bridge in calculating design seismic force. Hence, the seismic coefficient as per IS code ranged from 0.05 in 1962 to 0.09 in 1984. With consideration of bridge flexibility in 2015 version, the coefficient is 0.12 for $T=0.5$ and is 0.065 for $T=1.0$. The coefficient for the IRC was around 0.10 until the year 2000 when it became 0.18 for the rigid structure ($T=0.5$) and 0.098 for the bridge with $T=1.0$ sec. In later versions (2010 and 2014) of IRC, the coefficient has reduced considerably: 0.09 for rigid structure ($T=0.5$ sec) and 0.049 sec for bridge with $T=1.0$ sec. The coefficient for railway bridges in early years was to not exceed about 0.12; it became 0.09 in 1986. The IITK-RDSO guidelines provided coefficient of 0.18 for the rigid ($T=0.5$ sec) structure and 0.098 for the bridge with natural period $T=1.0$ sec. The more recent RDSO Guidelines provides coefficient of 0.113 for rigid ($T=0.5$ sec) structure and 0.061 for bridge with $T=1.0$ sec.

It is obvious that after the Indian bridge codes started to consider flexibility of bridge in computing design seismic force (something that is very logical and is done worldwide for a long period), the design force for the more flexible structures has reduced considerably. Further, there has been quite a bit of variation in the design force in different versions in the recent years; this is a reflection of the fact that the code committees are trying to balance the need for safety and rationality on one side, and avoiding significant increase in design force on the other side.

It may however be mentioned that design seismic coefficient is only one aspect of the seismic design. The actual design, both in terms of safety and the cost, depends not only on the design coefficient but on many other factors, such as a) method of design (limit state versus permissible stress design), b) the load factors and permissible stresses used in the design, and c) how natural period is calculated (for instance, if moment of inertia is being calculated based on cracked section of the reinforced concrete member, consideration of live load), etc.

The Way Forward and Work in Progress in IRC and BIS

Seismic provisions in BIS, IRC and IRS codes need to be further updated. The seismic provisions in IRC Bridge Code Section II (IRC: 6) relevant to the design of road bridges have undergone substantial changes recently to align these with the Limit State Method of design adopted in the IRC Concrete Bridge Code IRC: 112-2011. Clause No. 219 in the latest IRC: 6-2017 is a somewhat shorter version of the much detailed seismic provisions (Longer Version) being developed incorporating the modern thinking on the subject with scope for much detailed analysis to assess the strength of material and ductility.

BIS is also working on performance based design approach and soon there will be a published guideline for design of tall buildings with performance based approach.

A longer version of the Seismic Clause, which might be brought out as “*Guidelines for Seismic Design of Highway Bridges*” in line with similar AASHTO publication is one of the present mandates of the IRC committee. Towards this, Guidelines are proposed comprising various chapters on (a) Design Philosophy; (b) Design Methods; (c) Detailing, etc., besides introducing an *Explanatory Handbook* for use by designers.

Conclusions

Seismic provisions of first IRC Bridge Code, published in the year 1958 have undergone significant modifications during the last five decades based on increased understanding of earthquakes, the forces that come into play and the properties of the materials of construction over the design life of the structure. Continuous revision of the Seismic Clauses in IRC: 6 has been necessary to bring up the same at par with International Standards and also

conforming to the Limit State Method of design adopted in the IRC Concrete Bridge Code IRC: 112-2011 and relevant BIS publication IS: 1893 – Part 3. The major aspects covered in the latest IRC: 6-2014 pertain to inclusion of an appropriate map of seismic zones as per IS 1893, introduction of Response Reduction Factor, Importance Factors, Limit State Method of design and provision for Ductile Detailing, etc. IRC is expected to finalize the longer version of the Seismic Clause in the form of detailed Guidelines in near future.

Evolution of seismic provisions for railway bridges since its first publication (1941) and first revision (1964) to publication of RDSO guidelines (2015) for seismic design of railway bridges has been substantial. As things stand today, there are significant variations in seismic provisions for bridges in IS 1893, IRC 6 and Railway codes, which need to be narrowed down and one uniform understanding and methodology adopted across all the three codes.

References

1. IS 1893-Part 1 (2016). 'Criteria for earthquake resistant design of structures: Part-1, general provisions and buildings (Sixth revision)', Bureau of Indian Standards, New Delhi
2. IRC-6 (1958). 'Standard specification and code of practice for road bridges (Section II) - loads & stresses', Indian Roads Congress, New Delhi.
3. IRC-6 (1964). 'Standard specification and code of practice for road bridges (Section II) (second revision) - loads & stresses', Indian Roads Congress, New Delhi
4. IRC-6 (1966). 'Standard specification and code of practice for road bridges (Section II) (third revision) - loads & stresses', Indian Roads Congress, New Delhi
5. IRC-6 (2010). 'Standard specification and code of practice for road bridges (section ii) (fifth revision) - loads & stresses', Indian Roads Congress, New Delhi
6. IRC-6 (2014). 'Standard specification and code of practice for road bridges (Section II) - loads & stresses (revised edition)', Indian Roads Congress, New Delhi
7. BRIDGE RULES (1941). 'Bridge Rules', Ministry of Railways, New Delhi
8. IITK-RDSO GUIDELINES (2010). 'IITK - RDSO guidelines on seismic design of railway bridges: provisions with commentary and explanatory examples', RDSO, Lucknow.
9. IS 1893 (1984) 'Criteria for earthquake resistant design of structures (fourth revision)', Bureau of Indian Standards, New Delhi
10. Paper No.112 (1946). 'Standard specification and code of practice for road bridges (Section II)', Journal of IRC, Vol X.
11. IRC-78 (1980). 'Standard specification and code of practice for road bridges (Section VII) (First Published) – Foundations & Substructure', Indian Roads Congress, New Delhi
12. BRIDGE RULES (1964). 'Bridge Rules', Ministry of Railways, New Delhi
13. RDSO GUIDELINES (2015). 'RDSO Guidelines on seismic design of railway bridges, published by bridge & structures directorate', RDSO, Lucknow.
14. IS 1893-Part 3 (2014). 'Criteria for Earthquake Resistant Design of Structures; Part-3 Bridges & Retaining Walls', Bureau of Indian Standards, New Delhi

Table-1: Significant Earthquakes in and around India

S. No.	Date	Epicentre		Region	Magnitude
		Lat (°N)	Long (°E)		
1	1819 Jun 16	24.0	70.0	KUTCH, GUJARAT	8.0
2	1869 Jan 10	24.5	92.5	NEAR CACHAR, ASSAM	7.5
3	1885 May 30	34.1	74.8	SOPORE, JAMMU & KASHMIR	7.0
4	1897 Jun 12	25.9	91.0	SHILLONG PLATEAU	8.7
5	1905 Apr 4	32.3	76.3	KANGRA, HIMACHAL PRADESH	8.0
6	1918 JUL 8	24.5	91.0	SRIMANGAL, ASSAM	7.6
7	1930 Jul 3	25.8	90.2	DHUBRI, ASSAM	7.1
8	1934 Jan 15	26.6	86.8	BIHAR-NEPAL BORDER	8.3
9	1941 Jun 26	12.4	92.5	ANDAMAN ISLANDS	8.1
10	1943 Oct 23	26.8	94.0	ASSAM	7.2
11	1950 Aug 15	28.5	96.7	ARUNACHAL PRADESH-CHINA BORDER	8.5
12	1956 Jul 21	23.3	70.2	ANJAR, GUJARAT	7.0
13	1967 Dec 11	17.4	73.7	KOYNA, MAHARASHTRA	6.5
14	1975 Jan 19	32.4	78.5	KINNAUR, HIMACHAL PRADESH	6.2
15	1988 Aug 6	25.1	95.1	MANIPUR-MYANMAR BORDER	6.6
16	1988 Aug 21	26.7	86.6	BIHAR-NEPAL BORDER	6.4
17	1991 Oct 20	30.7	78.9	UTTARKASHI, UTTARAKHAND	6.6
18	1993 Sep 30	18.1	76.6	LATUR-OSMANABAD, MAHRASHTRA	6.3
19	1997 May 22	23.1	80.1	JABALPUR, M.P	6.0
20	1999 Mar 29	30.4	79.4	CHAMOLI, UTTARAKHAND	6.8
21	2001 Jan 26	23.4	70.3	BHUJ, GUJARAT	7.7
22	2004 Dec 26	3.3	96.1	OFF WEST COAST OF SUMATRA	9.3
23	2005 Oct 8	34.5	73.1	MUZAFFARABAD	7.6
24	2011 Sep 18	27.8	88.1	SIKKIM-NEPAL BORDER	6.9

Table 2: Soil-Foundation System Factor per IS 1893- 1970, 1975 and 1984

Soil Type	Values of \hat{a} for			
	Bearing Piles Resting on Type I Soils or Raft Foundations	Friction Piles, Combined Isolated RCC Footings without or with Tie Beams	Isolated RCC Footing Tie Beams or Unreinforced Strip Foundations	Well Foundations
I – Hard Soils	1.0	1.0	1.0	1.0
II – Medium Soils	1.0	1.0	1.2	1.2
III – Soft Soils	1.0	1.2	1.5	1.5

Table 3: Effect of Soil Conditions on Spectral Accelerations as per IS 1893 (Part-1)-2002

<p>For Type I Rocky or Hard Soil Sites: These are the soil having standard penetration value, $N > 30$.</p>	$\frac{S_a}{g} = \begin{cases} 1 + 15 T & 0.00 < T < 0.10 \\ 2.50 & 0.10 = T = 0.40 \\ 1.00 / T & 0.40 = T = 4.00 \end{cases}$
<p>For Type II Medium Soil Sites: These are the soils with $10 < N < 30$.</p>	$\frac{S_a}{g} = \begin{cases} 1 + 15 T & 0.00 = T = 0.10 \\ 2.50 & 0.10 = T = 0.55 \\ 1.36 / T & 0.55 = T = 4.00 \end{cases}$
<p>For Type III Soft Soil Sites: These are all soils with $N < 10$.</p>	$\frac{S_a}{g} = \begin{cases} 1 + 15 T & 0.00 = T = 0.10 \\ 2.50 & 0.10 = T = 0.67 \\ 1.67 / T & 0.67 = T = 4.00 \end{cases}$

Table 4: Response Reduction Factor per IRC-6: 2010

Bridge Component	R with ductile detailing	R without ductile detailing
Superstructure	N.A	2.0
Substructure		
(i) Masonry/PCC piers, abutments	-	1.0
(ii) RCC short plate piers where plastic hinge cannot develop in direction of length and RCC abutments	3.0	2.5
(iii) RCC long piers where hinges can develop	4.0	3.3
(iv) Column	4.0	3.3
(v) Beams of RCC portal frames supporting bearings	1.0	1.0
Bearings	2.0	2.0
<p>Connectors and Stoppers (Reaction blocks) Those restraining dislodgement or drifting away of bridge elements.</p>	<p>When connectors and stoppers are designed to withstand seismic forces primarily, R value shall be taken as 1.0. When connectors and stoppers are designed as additional safety measures in the event of failure of bearings, R value specified in Table 8 for appropriate substructure shall be adopted.</p>	

Table 5: Importance Factor for IRC 6: 2010

Seismic Class	Illustrative Examples	Importance Factor ‘I’
Normal bridges	All bridges except those mentioned in other classes	1
Important bridges	a) River bridges and flyovers inside cities b) Bridges on National and State Highways c) Bridges serving traffic near ports and other centers of economic activities d) Bridges crossing Railway lines	1.2
Large critical bridges in all Seismic Zones	a) Long bridge more than 1km length across perennial rivers and creeks b) Bridge for which alternative routes are not available	1.5

NOTE: While checking for seismic effects during construction, the importance factor of 1.0 should be considered for all bridges in all zones.

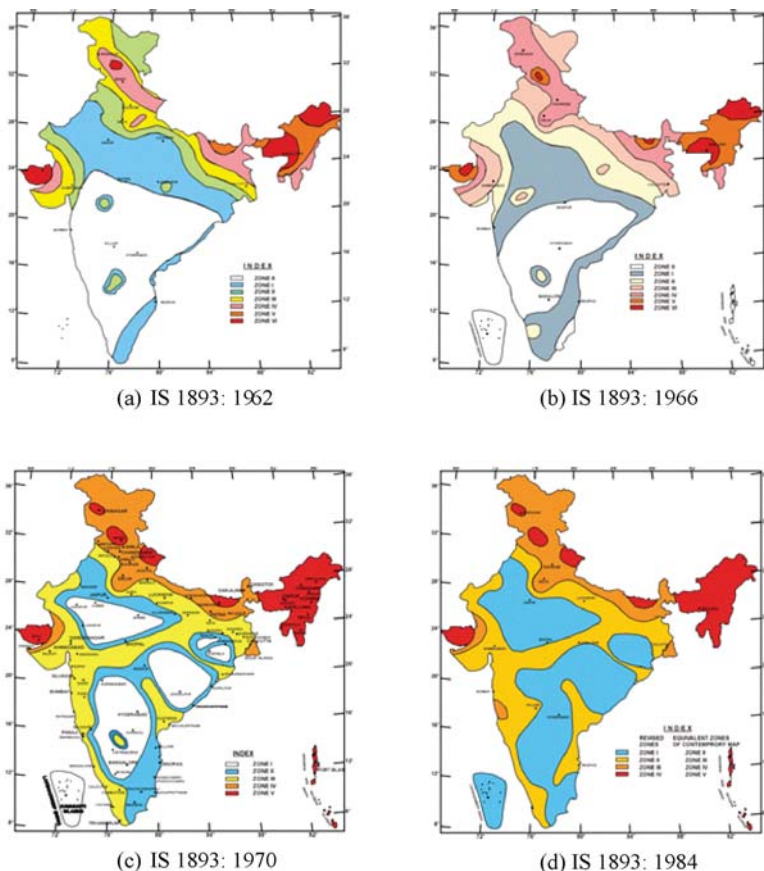


Figure 1: Evolution of Seismic Zone Map in IS 1893



Figure 2: First ever Seismic Zone Map of India: documented in IRC-6: 1958

Table 6: Response Reduction Factor as per IRC-6: 2014

Sl. No.	Bridge Components	'R' with Ductile Detailing	'R' without Ductile Detailing (for Bridges in Zone II only)	
1	a) Superstructure of integral / Semi integral bridge / Framed bridges	2.0	1.0	
	b) Other types of Superstructure, including precast segmental constructions	1.0	1.0	
2	Superstructure			
	(i) Masonry / PCC Piers, Abutments	1.0	1.0	
	(ii) RCC wall piers and abutments in longitudinal direction (where hinges can develop)	1.0	1.0	
	(iii) RCC wall piers and abutments in direction (where hinges can develop)	3.0	2.5	
	(iv) RCC Single Column	3.0	2.5	
	(v) RCC/ PSC Frames	a) Column	4.0	3.0
		b) RCC beam	3.0	2.0
		c) PSC beam	1.0	1.0
(vi) Steel Framed Construction	3.0	2.5		
(vii) Steel Cantilever Pier	1.5	1.0		
3	Bearings and Construction (see note v also)	1.0	1.0	
4	Stoppers (Reduction Blocks) Those restraining dislodgement or drifting away of bridge elements. (see Note (vi) also)	1.0	1.0	

Notes:

- i) Those parts of the structural elements of foundations which are not in contact with soil and transferring load to it, are treated as part of sub-structure element.
- ii) Response Reduction Factor is not to be applied for calculation on displacements of elements of bridge and for bridge as a whole.
- iii) When elastomeric bearings are used to transmit horizontal seismic forces, the response reduction factor (R) shall be taken as 1.5 for RCC substructure and as 1.0 for masonry and PCC substructure.
- iv) Ductile detailing is mandatory for piers of bridges located in Seismic Zones III, IV and V and when adopted for bridges in Seismic Zone II, for which "R value with ductile detailing" as given in Table 9 shall be used.
- v) Bearings and connections shall be designed to resist the lesser of the following forces, i.e., (a) design seismic forces obtained by using the response reduction factors given in Table 9 and (b) forces developed due to over strength moment when hinge is formed in the substructure
- vi) When connectors and stoppers are designed as additional safety measures in the event of failure of bearings, R value specified in Table 9 for appropriate substructure shall be adopted.

Table 7: Variation in Seismic Coefficient (A_h) for design of bridges as per various Indian seismic codes
(considering a river bridge located in Delhi, in medium soil (Type II), supported on well foundation, with RC circular pier)

Code / Guideline	Eq. Seismic Coefficient, A_h		Salient features of the code
	Time period T = 0.5 sec	Time period T = 1.0 sec	
BIS Code : IS 1893 (applicable for highway / railway bridges)			
1 IS 1893-1962	0.050	0.050	First BIS Code; Seven Seismic Zones in the map $A_h = 0.05$ for Delhi. Delhi was in Zone III in 1962
2 IS 1893-1966	0.060	0.060	Zoning Map revised. $A_h = 0.06$ for Delhi, which was put in Zone IV
3 IS 1893-1970	0.060	0.060	Seismic Zoning Map revised. Five Seismic Zones in the map.
4 IS 1893-1975 & 1984	0.090	0.090	Soil Foundation Factor introduced $\dot{a}_0 = 0.05$, $\beta = 1.2$, $A_h = 0.06$
5 IS 1893 (Part 3) -2015	0.120	0.065	Response Spectrum method and Importance Factor introduced in code. $\dot{a}_0 = 0.05$, $\beta = 1.2$, $I = 1.5$, $A_h = 0.09$ Recently published code with very stringent provisions. $Z = 0.24$, $I = 1.2$, $Sa/g = 2.5$ (1.36) for $T = 0.5$ (1.0) sec. respectively, $R = 3.0$ for Reinforced Concrete pier with ductile detailing cantilever type, wall type; $A_{h,0.5} = 0.120$; $A_{h,1.0} = 0.065$
IRC Code: IRC - 6 (applicable for Highway Bridges only)			
1 IRC 6 - 1958, 1964, 1966 (first & second revisions)	0.100	0.100	Published before BIS Code in 1958. Country divided into 4 regions for seismic vulnerability. Subsequent revisions of code in 1964 & 1966 did not take cognisance of seismic provisions of BIS code, until 1979. $A_h = g/10 = 0.1$
2 IRC 6 - 1966 (with amendment in 1981)	0.090	0.090	Zone Factor, Importance Factor and Soil Factor introduced in line with prevailing IS 1893; $\dot{a}_0 = 0.05$, $I = 1.5$, $\beta = 1.2$, $A_h = 0.09$ (considering medium soil with well foundation)
3 IRC 6 - 2000 (fourth revision)	0.090	0.090	No change in seismic provisions of the code after 1981
4 IRC 6 - 2000 (fourth revision with amendment in 2003)	0.180	0.098	Amendments brought in line with provisions of IS:1893 (Part I) - 2002Z = 0.24, $I = 1.5$, $Sa/g = 2.5$ (1.36) for $T = 0.5$ (1.0) sec. respectively, $R = 2.5$, $A_{h,0.5} = 0.18$; $A_{h,1.0} = 0.098$

5	IRC 6 - 2010(fifth revision)	0.09	0.049	'R' factors and I.F are rationalised; Additional margin kept for foundation design (=1.25) to cover for the possible higher forces transmitted by substructure arising out of its overstrength. $Z = 0.24, I = 1.2, Sa/g = 2.5 (1.36)$ for $T = 0.5 (1.0)$ sec. respectively, $R = 4$ for RCC long piers with ductile detailing where hinges can develop; $A_{h,0.5} = 0.09$; $A_{h,1.0} = 0.049$
6	IRC 6 - 2014(revised edition with amendments up to January 2015)	0.090	0.049	$Z = 0.24, I = 1.2, Sa/g = 2.5 (1.36)$ for $T = 0.5 (1.0)$ sec. respectively, $R = 4$ for RCC long piers with ductile detailing where hinges can develop; $A_{h,0.5} = 0.09$; $A_{h,1.0} = 0.049$
IRS Code and IITK/ RDSO Guideline/ RDSO Guideline (applicable for Railway Bridges only)				
1	Bridge Rules, 1941	Not exceeding 0.125	Not exceeding 0.125	Zone Map was not recommended
2	Bridge Rules, 1964	Not exceeding 0.12	Not exceeding 0.12	Zone Map was not recommended
3	Bridge Rules, 1986	0.09	0.09	Response Spectrum Method and Importance Factor introduced in code. $\dot{a}_0 = 0.05, \beta = 1.2, I = 1.5A_h = 0.09$
4	IITK/ RDSO Guideline - 2010 (published in November 2010)	0.18	0.098	Published at the behest of RDSO, necessitated due to absence of BIS code on bridges since publication of IS 1893 (part I) - 2002 with revised seismic map and revised zone factors. $Z = 0.24, I = 1.5, Sa/g = 2.5 (1.36)$ for $T = 0.5 (1.0)$ sec. respectively, $R = 2.5$ for RCC piers with ductile detailing – Single Column; $A_{h,0.5} = 0.18$; $A_{h,1.0} = 0.098$
5	RDSO Guideline - 2015 (published in January 2015) (*) Bracketed values applicable for Foundation design	0.113 (0.141)*	0.061 (0.076)*	RDSO modified the IITK/RDSO Guideline and diluted the 'R' factors in line with the IRC codes. $Z = 0.24, I = 1.5, Sa/g = 2.5 (1.36)$ for $T = 0.5 (1.0)$ sec. respectively, $R = 4$ for long RCC Piers where hinges can develop; $A_{h,0.5} = 0.113$; $A_{h,1.0} = 0.061$

Proposed Alternative Mechanisms to Award Works Contracts



Mr. K K Kapila
*Chairman & Managing Director, Intercontinental Consultants
 and Technocrats Pvt. Ltd*

INTRODUCTION

The international consulting engineering community by and large is publically judged by the performance of the world's physical or built infrastructure. While they are responsible for the design of the infrastructure, the actual construction work is performed by contractors. Successful construction is dependent on implementation of the engineers' designs into the completed project. Critical to achieving this success is the method used to select and award work to construction contractors. The purpose of this paper is to identify alternative best practices for contractor selection that can be applied world-wide, depending on the complexity of the project and the procurement and technical sophistication and capacity of the procuring entity.

FIDIC has recently done a survey of its world-wide member associations and multilateral development banks (MDBs), to better understand the current contracting practices used and how successful they are. The survey reveals that there is a need for change.

Some of the notable survey results are:

1. Most countries have separate procurement laws for construction work.
2. Advertising in public sources is commonly done.
3. Almost all require some sort of qualifications and technical proposals.
4. For countries, a small majority prequalify/short list firms but less than one-half require technical proposals however, they don't consider sustainability, long-term performance and operational cost in decisions.
5. For MDBs, short listing based on qualifications and evaluation of technical proposals is required.
6. Nearly 60% of the countries award contracts based on quality and price or on average price method, nearly 40% countries follow award of contracts on Least Cost.
7. It was almost unanimous that lowest bids are a problem, causing overruns, scheduling problems, disputes, and contract terminations and do not serve either the owners or the contractors, or the public.
8. All agreed that lowest bids have a negative effect on relationships.
9. Over 75% stated that lowest bids increase engineering costs.
10. The majority (61%) want FIDIC to produce a Best Practice Guideline for awarding work to contractors, with another 31% preferring FIDIC generate a policy paper.

Under the lowest bid method, the construction firm submitting the lowest bid receives the right to the construction contract. Its perceived advantage is that it forces contractors to continuously try to lower costs by adopting cost-

saving technological and managerial innovations. These savings are then passed on to the owner through the competitive process. An owner runs a significant risk of selecting a contractor that has either accidentally or deliberately submitted an unrealistically low price. A contractor cannot adhere to such a price and at the same time expect to complete the project according to plans and specifications, and also make a reasonable profit. This may lead to the contractor generating excessive claims and disputes arise during construction which lead to litigation, schedule delays, compromises in quality, increased costs, and sometimes defaults.

Attempts by owners to mitigate artificially low bids and recommended alternative contractor selection approaches have included:

1. Prequalification and short listing, based on a well-defined criteria, in order to limit the number of bidders and thereby the pressure for a contractor not to submit unrealistically low bids or not bid at all.
2. Using a realistic approach to find a reasonable bid (suitable to the local situations and environment) that should reflect reality and not misunderstanding, errors, or desperation.
3. Requiring and evaluating project specific Technical Proposals, along with Cost Proposals, in order to understand a bidder's approach and select the "best value" offer.

PREQUALIFICATION AND SHORTLISTING OF CONTRACTORS

Limiting the number of bidders increases the probability of any one bidder being able to win the work. While this encourages the firms short listed to submit bids, it does not eliminate the potential for mistakes or desperate offerors to submit artificially low bids. The shortlisting criteria given below are meant to determine most appropriate bidders from amongst the prospective bidders.

For effective prequalification and shortlisting process, a well-structured Expression of Interest (EoI) is to be widely published. The criteria for prequalification and evaluating the submissions have to be clearly spelled out in the EoI. Shortlisting should limit the number of firms to those with distinctly superior qualifications.

The shortlisting criteria should generally include the following:

1. Company details, history and commitments (focused on the last 5 years, but allowing older relevant examples)
 - 1.1 Details of work performed as Prime Contractor.
 - 1.2 Details of Projects Completed (similar nature and in same geographical area).
 - 1.3 Details of conformance to environmental codes and sustainability, labour safety, employee rights, security standards, and other governmental or third party requirements.
 - 1.4 Details of the current projects of similar nature under execution.
2. Plant & equipment, personnel and sub-contractors
 - 2.1 Major items of Contractor's equipment proposed for carrying out the Works.
 - 2.2 Qualifications and experience of key personnel proposed for administration and execution of the Contract.
 - 2.3 Availability of equipment and personnel to perform the Works, considering the extent and scheduling of current projects being performed or recently awarded.

3. Financial details and legal status
 - 3.1 Financial references of the Bidder's main Bank.
 - 3.2 Current financial details (attach financial statements & profit/loss statements for the previous 5 years).
 - 3.3 Details of current litigation involvement.
4. Reference checks from the clients of the completed projects to know the Contractors performance including any litigation history.

RECOMMENDED CONTRACTOR SELECTION APPROACH

Once the Contractors are shortlisted/prequalified on the basis of a pre-determined criteria as discussed above, it is assumed that the shortlisted Contractors are qualified enough to execute the projects. While many Owners are able to estimate approximate construction cost, often the Contractor's proposals vary considerably from that estimate, due to different understanding, approaches, means, methods, and sequencing of work. Contractor selection requires varying approaches to deal with valuing the proposals presented. The possible approaches of selection of Contractor could be grouped under three main broad criteria with sub-groupings under each approach:

(A) Lowest Workable Cost Approach.

- (1) Selection based on Average Bid approach,
- (2) Selection based on the Contract price closest to the average bid price after elimination of abnormally low & high bidders and
- (3) Selection based on Lowest Reasonable Cost

(B) Cost and Quality Approach (weightage of technical and cost score applied).

- (1) Selection Based on Technical and Cost Scores, and
- (2) Selection Based on Best Value Approach

(C) Quality Approach (selection based on highest technical score).

- (1) Qualifications Based Selection (QBS) method, and
- (2) Selection Based on the Highest Technical/Performance Score established on Owner's Budget

These are discussed below.

A. Lowest Workable Cost Approach (this approach is to identify an appropriate bidder with reasonable cost):

- 1. Selection based on Average Bid approach:** This could be as simple as using the 'average bid', arithmetic average approach. The process is to calculate the arithmetic average bid price of the bids and award the contract to a bidder whose bid price is nearest to the average bid price.

For example, if the bid prices are 82,250, 84,650, 86,250, 88,950 and 90,150 respectively, then the average bid price is 86,450. The award goes to the bidder whose bid price is 86,250, as this price is the nearest to the average bid price.

- 2. Selection based on the Contract price closest to the average of bid price after elimination of abnormally low & high bidders:** Once the bids are opened, the financial bids of the technically qualified bidders are compared. The bidders whose bid price are beyond +/- 10% of the average bid price are rejected. The lowest of the remaining bids are considered for award. See example as below:

Firm	Bid price	Average bid price	Range of +/-10%	Rejection	Rank
A	100,000	99,666	89,699 – 109,632	Beyond range	03
B	110,000				
C	90,000				01
D	85,000			Beyond range	
E	115,000			Beyond range	
F	98,000				02

This selection process would be ideal for non-complex projects and procuring entities with minimal procurement and technical sophistication and capacity. But the process of evaluation as mentioned above and the comparison of bids has to be clearly specified in the bidding documents in the Bid Data Sheet (BDS) (under relevant chapters) so that the prospective bidders are well aware of the evaluation technique.

3. Selection based on Lowest Reasonable Cost

For non-complex projects and procuring entities with minimal procurement and technical sophistication and capacity, this two-step approach to the procurement of a construction contractor retains the benefits of prequalification and shortlisting. The first step is to solicit bidders to provide qualifications to do the work based on the type of project, location, schedule, and other criteria/factors that allow the potential bidders to determine if they can do the work and are likely to win the contract. The bidders submit relatively inexpensive, but responsive qualifications submittals and back up information, including information on example projects and appropriate contacts, to verify performance.

Based upon the qualification packages received, the owner identifies the bidders that have the capabilities, resources, experience, reputation, local knowledge, and other attributes that should lead to a successful project completion. If the number of qualified bidders is too large, to encourage competitors to remain engaged in the procurement (low probability of winning), the owner ranks the qualified bidders based on pre-established scoring of the criteria. If there is a natural break in the scoring of the top 3-5 bidders, they become the short list. If the natural break in scores is higher, the list can be expanded. Minimizing the number of bidders avoids unnecessarily burdening bidders with proposal costs that probably will not result in their winning the work but helps in controlling the owner’s internal procurement process costs.

The second step is to request cost proposals for the specific project from the short listed bidders. The cost proposals are analysed to identify artificially low or high bids and then a bidder is selected based on the lowest cost or the closest to the average cost (as discussed earlier in this paper) of the proposals.

B. Cost and Quality Approach (weightage of technical and cost score applied):

- 1. Selection Based on Technical and Cost Scores -** For more complex projects and more sophisticated procuring entities, a methodology that balances technical capabilities, project approach, and proposed cost of the bidders is sought. It is to request technical and cost proposals for the specific project from the short listed bidders. Included in the request for proposals would be a preliminary scope of services (terms of reference) and the evaluation criteria and scoring for the technical and cost proposals.

The performance requirements and other fixed portions of the scope of services should be identified, with innovation and changes to the scope encouraged. The contents of the Technical Proposal should address the bidder's approach to meeting all of the challenges and requirements of the project. The performance requirements should be considered while ranking the bids and should include any specialized input of resources to complete the project, along with lesser cost and time, proposed risk management and mitigation plan, protection of social and environmental standards, safety standards, adoption of environment friendly construction techniques, etc.

The Technical Proposals are then evaluated and scores given based on pre-established criteria. A table of scores is established and, based on natural divisions in score totals, the procuring entity can retain all bidders or further limit the selection to those bidders over a certain achieved score. Once the technical scores are established, the Cost Proposals of the remaining bidders are evaluated and scored. The procuring entity then decides which bidder provides the best combination of capabilities, approach, and cost. Often a weightage is applied to the technical and cost scores. To truly value the technical aspects of projects the weighting of the technical score should be at least 80% of the total score.

The selection criteria for technical and cost scores should be clearly specified in the bidding documents in the BDS (under relevant chapters) so that the prospective bidders are well aware of the evaluation technique being used.

2. **Selection Based on Best Value Approach** - The Best Value Bidder is selected after given due weightage to the four factors (price, project capability, risk assessment plan, and value added plan). The Bidders document should include these four factors.

The final selection modality is similar to quality and cost value approach. The good thing in this approach is that the best two or three bidders are interviewed before the final ranking is prepared. The quality/price weightages can vary, with at least 80/20 recommended. The recommended weightage of Interviews is 30%, Project capability 15%, Risk Assessment Plan 20% and Added Value Plan 15%.

C. Selection based on Quality Approach (selection based on highest technical score)

1. **QBS method**, as described in the Associated General Contractors of America *Qualifications Based Selection of Contractors* publication, dated August 2009, creates a focus on quality and value only, not price. The most qualified vendor is selected on the basis of demonstrated competence, project approach, and ability to perform only. Criteria, like experience and past performance of the firm and the key individuals, capacity, financial strength, management plan, safety plan, quality assurance plans, are considered while ranking the bids/proposals.

The agency head/procurement head shall negotiate final scope and cost with the highest qualified firm at a compensation which the agency head determines is fair and reasonable.

2. **Selection Based on the Highest Technical/Performance Score Established on Owner's Budget** - For procuring organisations with full technical and procurement capabilities and capacity, wishing to achieve the most project performance within an established budget, an alternative best practice is offered here. It is to request technical proposals, based on the provided scope of services and project budget (cost and schedule). In addition to the bidder's approach to accomplishing the project, the bidder is asked to identify what scope and performance requirements can be completed within the budget identified by the owner and what cannot be done and should be deferred. If all scope and performance requirements can be completed within budgeted

cost and schedule restraints, the bidder should identify proposed additional enhancements or improvements that can be obtained without adding cost or time. The owner should identify whether cost or schedule is dominant in their decision making and if the bidder can adjust either of them to better the project value delivered.

PROS AND CONS OF ALTERNATIVES

While the alternatives identified basically combine the best attributes of the mitigating approaches being explored by many owners, they present certain benefits and challenges to the owner, and therefore to FIDIC, in developing a best practice.

The **benefits** include:

1. Ascertaining the best value to the Owner.
2. Avoiding damaging too low bids.
3. Nurturing more and better competition.
4. Encouraging innovation by bidders.
5. Arriving at more accurate construction budgets and schedules.
6. Providing standardization for the construction sector.
7. Eliminating construction firms that have inadequate experience and capability to deliver the desired project.
8. Educating both Owners and Contractors on procurement considerations that lead to successful projects.

The **challenges** include:

1. Overcoming the allure of the simplicity of selecting the lowest bidder.
2. Explaining and educating owners on the positive aspects of the alternative methods.
3. Developing or providing the necessary skills for owners to use the alternatives.
4. Convincing the government, public, and media that low price is rarely the best approach for physical infrastructure projects.
5. Getting the construction contractors to accept new award methodology. The bidding document has to be very clear and lucid on the proposed method of evaluation and selection criteria and specified stipulations must be there in the bidding documents in the BDS (under relevant chapters) so that the prospective bidders are well aware of the evaluation technique.

INDIA'S FIRST MADE-IN-INDIA ZERO EMISSION ELECTRIC BUS was launched in October 2016, by commercial vehicle major Ashok Leyland. The company has invested Rs 150-200 crore to develop this new 'Circuit' series in India, expected to be the next generation technology. Ashok Leyland owns an UK firm, Optare, which is a leading alternate technology player, especially in electric bus manufacture. The vehicle would cost around Rs 1.5-3 crore, depending on the batteries and seats. Upfront cost is high, but it can deliver payback to the customer in about four-five years, say company officials. The buses are all exclusively engineered on India-specific platforms that could tackle varied topography, gradients, and usage conditions. Integrated with a fire detection and suppression system, this vehicle can travel 120 km on a single charge.



Brief Proceedings of the Third Asia - Pacific Conclave on Dry Extraction & Effective Utilization of Bottom Ash & Technological Advances in other Coal Combustion Products and Emissions in Thermal Power Plants

Mr. Mainak Ghosal

Consultant, Banking & Construction Industry; Joint Secretary & Convener (Technical & Scientific Committee) - Coal Ash Institute of India

Introduction:

Coal Ash Institute of India (CAII) established in 1994, a non-profit organization for promoting coal combustion products organized their 3rd Asia Pacific Conference (the previous two were held on 2007 & 2013 on different aspects of coal combustion products) on *Dry Extraction & Effective Utilization of Bottom Ash & Technological Advances in other Coal Combustion Products & Emissions in Thermal Power Plants* on 17-18th March, 2017 at Hotel Pride Plaza, Kolkata. Coal-one of the major energy resources in power generation (pegged to leapfrog from 187GW to 237GW by 2022 as per Central Electricity Authority, where as no coal based Thermal Power Plants (TPP) has come up in China after 2013) has led to 3 major environmental problems in Asia Pacific (particularly in India):

- ✓ Huge gap between the generation & utilization of Coal Ash (1 Ton of ash consumes nearly 1sq.m of land but 56% utilization compared to prescribed 100%, as per GOI norms with 54 plants out of 151 achieving the target).
- ✓ Collection problem of Bottom Ash (coal ash contains 20% bottom ash & 80% fly ash) in dry state (existing practice of wet extraction of bottom ash hindering properties that are required for its gainful use) for effective usage, and
- ✓ Air Pollution Control [MoEFFCC notification states that new TPPs commissioned after 1 January 2017 should follow the emission norms given below. Particulate Matter 30mg/Nm³, SO₂ 100mg/Nm³, NO_x 100mg/Nm³ but which are substantially lower than the existing units norms of PM, SO_x, NO_x of 100, 600 & 600 mg/Nm³] in terms of PM, SO_x, NO_x & heavy metal discharges (Hg 0.03 mg/Nm³) with zero liquid discharge. Globally, ash handling & engineering companies have designed & implemented systems by which bottom ash are extracted, cooled & conveyed in a dry state but with limited appearance in the Indian TPPs.

Brief Discussion:

The conclave which was event managed by *Corporate Monitor* evoked a good response from within and outside India. More than 100 delegates took active participation in this event including delegates from Europe and China. The Key-Note Addresses were presented in a Plenary Session by Mr. B Sengupta, former Member Secretary of the Central Pollution Control Board, New Delhi on Environmental Norms and Regulations; Mr. Tomasz Szczgielski, Warsaw University of Technology, Poland on Zero-Waste Coal Power Strategy; Mr. G Thakur, Chief Engineer, Central Electricity Authority, New Delhi on Fly Ash Utilization in India; Mr. Andrei Gorjup of RUDIS, Slovenia on Flue Gas Desulfurization Technology; and Professor V K Agrawal, Indian Institute of Technology, New Delhi on Future Research Vision on Fly Ash Handling. Four Technical Sessions were organized on themes such as “Dry Bottom Ash Extraction and Utilization”, “Innovative Technologies in Coal Ash” “Abatement of Air Pollution in Thermal Power Plants and Other Processing Industries” and “Fly Ash



Sri Sovandeb Chattopadhyay, Hon'ble Power Minister, GoWB along with Mr. David Harris, President Asian Coal Ash Association inaugurating the Conclave by lighting the Lamp

Transport, Management and Processing Equipment” over the two days of the Conclave in which a total of 21 Papers were presented. In addition, the conclave programme included a Panel Discussion on Coal Ash Based Products and Technologies, moderated by Mr David Harris, President, Asian Coal Ash Association, and it ended with a Valedictory Session which was addressed by the Mr T Chakravarty, a Senior Environmental Consultant, formerly of Steel Authority of India. From amongst the 145 Thermal Power Plants in India persons from only DVC and CESC participated.

Major Highlights of the Conclave:

- ❖ As the present cost for De-pollution is Rs. 1Cr/MW/per 100mg/Nm³, hence the concept of circular economy and its application to solving the coal ash problems.
- ❖ Urgent need to expand the scope of utilization of fly ash from the present level of about 60% to 100%. It seems that areas like road and bridge construction, laying of railway tracks, agriculture, forestry, cement and concrete making, mine filling, ash-park development, etc. have further opportunities of increasing the use of fly ash.
- ❖ For expanding the scope of fly ash use, the development and use of geo-polymer products appears to be a very promising avenue. GeoPolymers are a technologically interesting group of materials that are already being used in various niche concrete applications such as coastal protection armours, fire and heat resistant building components, toxic wastes encapsulation, etc. Further application development efforts need to be directed towards its use in pavement blocks, tiles, shotcreting, acid-resistant surface coating, sewerage pipes, instant road repair, ceramics, fillers in polymers, plastics, rubbers, extender in paints, etc.
- ❖ It was reported by the National Metallurgical Laboratory of India that they had set up the first pilot plant to produce paving blocks by the geo-polymerizing process.
- ❖ The National Aluminium Company in India, being a large generator of coal ash from its captive power plant, has been exploring eco-friendly technologies for bulk management of ash. One of the technological options being examined by this company is the extraction of smelter grade alumina and high purity alumina from fly ash as there would be adequate scope for in-house consumption of such products.
- ❖ For increasing the proportion of fly ash in the blended cement, already being produced in India in large quantities, certain technological options were presented. One such technology is the adoption of LNVT

vertical roller mill which is capable of handling both fly ash and bottom ash for grinding purposes. Another option is to adopt the technology of classification and processing of fly ash with the help of steam jet mill developed by Shandong PingyiKaiyuan New Building Material Company of China so that fine and ultrafine fly ash could be used in the blended cement and concrete in enhanced proportions.

- ❖ Quite different from fly ash, the bottom ash is a dark grey granular sand size material that is generally collected wet from the furnace bottom and conveyed to a disposal pond by high pressure water jets. The technological advances have now opened up opportunities of transferring the bottom ash to a decanting basin for dewatering, crushing and stockpiling. In fact the possibilities of drying, decarbonising and further processing of the dry bottom ash are now available. The dry processed bottom ash can serve well as sand substitute in cement concrete or in asphalt concrete, apart from its use as a raw feed for cement kilns, laying of road base and sub base, etc. Since 20% of the total coal ash is collected as bottom ash, the technological advances in this field are of great economic significance.
- ❖ Issues relating to ash handling have been discussed. Although dry fly ash handling systems are well established, most plants face the problem of achieving the design capacity. Another aspect of concern is the power consumption. The variation in the quality of ash is known to be one of the reasons for the poor efficiency of the handling systems. In order to overcome these difficulties, a system of internal by-pass with two annular pipes, the internal one having holes at regular interval, has been proposed.
- ❖ In another presentation the technological needs for successful implementation of High Concentration Slurry Disposal (HCSD) systems for both bottom ash and fly ash have been emphasized. The significance of determining the economic slurry concentration, evaluating the slurry flow behaviour, assessing the settling characteristics have been elaborated and some of the pre-requisites for proper implementation of the systems have been explained.
- ❖ The stringent regulation of SO₂ emission in power plants and process industries like cement has now compelled the plants to look into Flue Gas Desulfurization (FGD) process. The major FGD technologies that include wet and dry scrubbing, sorbent injection, and sea water scrubbing and multi pollutants removal have undergone significant evolution in terms of process integration and cost-effective implementation. These aspects have been discussed and compared.
- ❖ The technology of Selective Catalytic Reaction (SCR) for reducing the NO_x emission and the researches carried out in China on the denitration technology has been presented by a few speakers. The recent process improvements have been specifically highlighted.



Fly Ash Aggregates (also called 'Coal Mill Rejects') displayed by students of IEST, Shibpur and the media - 'The Statesman' News Service coverage of the event.

- ❖ So far as the emission reduction technologies are concerned, the primary concerns are the high investment and economic viability. These concerns are more for the captive power plants in the process industries than in the large thermal power plants. It was also suggested that Fly ash utilization could be implemented as 'CSR Activity' measures.

Conclusion:In the Valedictory Session, apart from a very positive feedback from the audience, it was proposed that the Coal Ash Institute of India in collaboration with national and international partners should prepare a road map for the 100% utilization of

the coal ash generated in the country which is about 240 million tonnes at present. The Institute should also endeavour to enlist the breakthrough technologies being developed in the field of coal ash application with a rating of their probable commercial success. "It will be a good initiative to work with China in the field of fly ash utilization. We can study the best technologies of China and then absorb them along with the learnings about the manner in which it is to be done" added Mr. Anjan K Chatterjee, Chief Advisor of the Organizing Committee as reported in 'The Statesman' dated 21st March, 2017.

INDIA'S LONGEST HIGHWAY TUNNEL, CHENANI-NASHRI TUNNEL, on the Jammu-Srinagar national highway, was inaugurated by Prime Minister Narendra Modi in April 2017. The length of the tunnel is 9.28 km. It will reduce the travel distance between Jammu and Srinagar by 30.11 km, which will help save fuel worth Rs 27 lakh daily. Built on the lower Himalayan range at a height of 1,200 metres, it will cut travel time between the two cities by at least two hours. The project cost is Rs 3,720 crore, Rs 1,200 crore more than the initial estimated cost.

It is an all weather tunnel and bypasses 44 avalanche - and landslide-prone spots on the highway. The tunnel comprises two tubes - the 'main tunnel' and the 'escape tunnel'. The two are internally connected through 29 cross-passages; each is located 300 metres apart. Such a long tunnel could present the problem of a lack of oxygen. To ensure there is no excessive carbon-dioxide build up inside the tunnel, there are several exhaust meters that will check the air all through the length of the tunnel.

CEAINEWS

SEMINAR ON “PORTS AND INDUSTRIAL CORRIDORS” – A REPORT

CEAI successfully conducted a Seminar on ‘Ports & Industrial Corridors’ on 7th April 2017 at the India International Centre, New Delhi.

The seminar was designed for one full day with participation from all the stakeholders of ports, industrial corridors, logistics & cargo operators, consulting engineers, dredging companies and representative from central and state government agencies, etc.

The seminar was supported by Sagarmala – Ministry of Shipping, DMICDC and PIANC.

The seminar comprised three technical sessions and a panel discussion to conclude and make recommendations. The sessions were on,

- i. Ports
- ii. Industrial Corridors and Growth Centres
- iii. Connectivity and Logistics, and
- iv. Panel Discussion

Inaugural Session

The Inaugural Session commenced with welcoming the Hon’ble Chief Guest Shri Mansukh L Mandaviya, Union Minister of State for Road Transport, Highways, Shipping, Chemical and Fertilizers, Government of India and the Keynote Speaker Padmashree Dr. Z S Tarapore, with green saplings.



Hon’ble Minister Mr. Mansukh L Mandaviya, MOS, MoRTH, Shipping, Chemical and Fertilizer delivering the Inaugural Address

Ms. S Philip, President CEAI, accorded a warm welcome to the Hon’ble Chief Guest Shri Mansukh L Mandaviya, the Keynote Speaker Padmashree Dr.Z S Tarapore, all dignitaries and participants. She acknowledged the support and sponsorship from various prestigious organisations. The President spoke briefly about CEAI as an organization and the seminar theme.

Dr.Ajay Pradhan, Chairperson of Seminar Committee introduced the participants to the Seminar vision and objectives. Dr. Pradhan talked mainly of three key aspects towards the vision:



Releasing the Seminar Souvenir

1. Firstly, the hardware or the physical Infrastructure: The hardware is being built with a number of initiatives by the Government namely the DFCC, Industrial Corridors, Industrial Investment Regions, SEZs, FTZ, PCPIRs, Coastal Shipping with SAGARMALA Program, brownfield expansion of ports, development of greenfield ports, etc.
2. Secondly, the software – capabilities, processes, communications, solutions (Packaging & Logistics).

A coordinated approach is required for the purpose of connectivity, seamless movement of cargo from various sources to the hub and vice-versa so as to harness the economic development agenda of India.

3. Third, the Ecosystem:

This is of paramount importance wherein interdependency is understood, tolerances are built, collaboration is incentivized, policy is enabled, and

service quality is tracked and differentiated. In its entirety, all the stakeholders partner in the growth story.

Padmashree Dr.Z S Tarapore delivered the Keynote Address on ‘Ports and Environment; A need for Introspection’. Dr.Tarapore emphasized how the consulting engineers rose to meet the new challenges arising due to new environmental regulations especially in developing designs that were environment friendly and yet financially attractive to private port developers.



Padmashree Dr. Z S Tarapore, Former Director, CWPRS, presenting Keynote address

In this context, he mentioned that three areas needed to be focused upon as:

- a. Energy Policy and Import of Coal
- b. Coastal Harbours and handling of Littoral Drift
- c. Handling of Capital Dredging

He discussed about efficacy of various dredging technology and methods especially for Indian ports, in managing capital and maintenance dredging to overcome the challenges to meet the demand. In his concluding remark, he asked, should Consulting Engineers be recommending development of Green Ports?

The Hon’ble Union Minister of State for Road Transport, Highways, Shipping, Chemical and Fertilizers, Government of India delivered the inaugural address by enlightening the audience on the importance of various initiatives undertaken by his Ministry and the Government of India.

The Hon’ble Minister discussed the benefits of the Sagarmala Project to connect all maritime states to

improve the movement of cargo especially from Coastal Economic Zones (CEZ) to major ports and to other states as well. He added that the Sagarmala Project is a step towards the economic development of India through industrialization and Make in India. He emphasized the environmentally safe ship recycling facilities to attract the world’s aging ships to the Indian coasts. That would not only provide large scale opportunities to downstream industries but also provide scrap to our steel plants – therefore it was a win-win for everyone.

Session I: PORTS

Session I was devoted to the current infrastructure status of Indian Ports during which various constraints related to development and operation of ports were highlighted. The session was chaired by Padmashree Dr.Z S Tarapore, former Director, CWPRS, Pune. There were four speakers in the session. Mr. A N Aswatha, Director of Engineering of Ministry of Shipping presented the government’s new initiative on coastal shipping and Sagarmala. He also discussed about the incentives for coastal shipping and cargo movement including PPP.Mr. Srikumar Ghosh, honorary Vice President, PIANC presented and discussed the history of the International Navigation Association (PIANC), memberships and various initiatives undertaken to improve the waterborne transport system



Session 1 on Ports in progress

around the world and especially in India. Mr. Devdatta Bose, Sector Head – Ports, Tata Consulting Engineers (TCE), Mumbai talked about the smart port initiatives around the world, and provided an insight on development of future ports. Dr. Ruchi Kalra, Head of Ports & Maritime, DHI India presented the various

modeling aspects in relation to the design and development of ports including environmental monitoring.

Session II: Industrial Growth Centres

Session II was chaired by Mr. Paritosh Gupta, Chief Executive Office, IL&FS Infrastructure Development Company (IIDC), New Delhi. The initiatives undertaken by the government to create Industrial Investment Region, growth centres with challenges and opportunities to boost trade and commerce to achieve economic development were discussed. He highlighted the key challenges for PPP projects wherein huge investment are being made by private companies like IL&FS and others. Dr. Pawan Maini, CEO, SEMAC presented the green design initiatives at the micro level especially of the industrial clusters to improve overall environment sustainability. Mr. Anil Kumar, CH2M presented the case study of Shendra Bidkin Industrial Area (SBIA), an industrial node of the Delhi Mumbai Industrial Corridor Corporation (DMICDC), the flagship program of DIPP of the Ministry of Industry and Commerce, Government of India. The industrial node has been further developed as an Industrial City called AURIC or Aurangabad Industrial City. He showcased some of the world class design initiatives being implemented in developing the new industrial and smart city.



Session II on Industrial Growth Corridors

Session III: Port Connectivity & Logistics

Session III was chaired by Capt. S R Patnaik, Director & CEO, International Shipping and Logistics Ltd., Dubai. The session discussed complex issues on how to facilitate better shipping movements, cross-border

transport and cargo movement and environmental management with sustainability. Capt. Patnaik made a presentation on Indian Ports, their present capabilities in handling cargo and initiatives being taken to increase the additional capabilities including improving the operational efficiencies. He also presented case studies of some of the best operational ports in the world. He emphasized both port side and landside needs to integrate for better throughput of the Indian Ports. Mr. Atul Kulkarni, Advisor, Indian Ports Association (IPA) brought in issues related to port capabilities and lack of integration between port facilities, cargo handling and evacuation including connectivity and logistics. He highlighted the huge gap for seamless operation and integration between ports and road or rail connectivity. Besides, he also advocated other soft issues like policy for seamless movement of cargo from source in the hinterland to the port via many states and the hurdle of varying tax regime in each state. Mr. Amitabha Ghoshal, STUP consultants presented various design aspects in relation to augmentation of capacity of ports by bringing unique design aspects for retrofitting. He showcased some unique aspects in relation to the new handling system of coal and Oil at Paradip Port. Mr. A Brara, Chairman & Managing Director, Mantec Consultants Pvt. Ltd., spoke about environmental impact assessment and environmental management plan of ports and industrial corridor development projects. He



Session III –on Port Connectivity & Logistics.

Capt. S R Patnaik, Chairperson making his presentation also mentioned about environmental issues for oil spill and contingency plans.

Way Forward and Panel Discussions

The panel was chaired by Mr. K K Kapila, Chairman,

ICT Ltd, New Delhi. The panel also included Capt. S R Patnaik, Mr. Atul Kulkarni and Mr. Srikumar Ghosh.

1. Integration of both Hard and Soft Infrastructure: While physical infrastructure such as Ports, Roads, Railway and Industrial Corridors are being built - looking to integrate SEZs, availability of energy, Information Communication Technology (ICT) etc. on the one hand and on the other, creating clusters of economic activity to strengthen regional economic development, for instance, the regional food basket, local industry, capacity development and employment, and promote tourism and environmental sustainability.



Panel Discussion - Mr. K K Kapila in the Chair

2. To overcome number of challenges such as, multiple agencies, divergent priorities and approaches. Soft Infrastructure is always perceived as an afterthought and hence seamless integration remains wanting. A close parallel could be the great Indian Juggad vs a well thought out action plan.

In our view, the construct for maritime connectivity will sustain itself if it adopts an inclusive and symbiotic approach with these priority issues. An integrated and holistic Master Plan may be one of such ideas. There could be a possibility of Single Authority or Single Operators in long run.

Concluding Remarks

Mr. Sudhir Dhawan, immediate Past President, CEAI delivered the vote of thanks by thanking each and every one who participated in the Seminar. He felt that during the daylong seminar, there were key take away and learnings for each participant with respect to their respective domain for implementation. He had a special word of thanks for the sponsors and the organising committee for the success of this seminar.



Supporters

SPONSORS



SEMINAR ON “ENGINEERING FOR STATE-OF-THE-ART BUILT ENVIRONMENT”

CEAI teamed with WorldBuild India as the Knowledge Partner for the B2B event held from 20th to 22nd April 2017 at Mumbai.

CEAI’s Western Region Centre successfully conducted the seminar on “*Engineering for State-of-the-Art Built Environment*” at the WorldBuild India event on 21st April 2017 which blended with the theme of the exhibition to showcase new building materials, products and systems available in India.

The speakers were experienced engineers from their own sectors. The seminar was very well attended by around 125 persons who appreciated the presentations made by all the speakers. The seminar provided an avenue to bring practicing engineers up to date with the developments in different sectors which are all essential for a built environment.

At the inaugural session, Mr. Uttam Sengupta, Vice President CEAI and Chairman CEAI-WRC accorded a warm welcome to all the dignitaries and participants. He briefed them on CEAI and its activities and listed out some of large development schemes announced by the government which provide numerous opportunities for engineers to contribute to the growth of the country.

Mr. Shreegopal Kabra, Managing Director, R R Global, who had sponsored the seminar, welcomed the speakers and the participants. He spoke of the Growth that his company had made since its incorporation in 1998 as R R Kabel and its new avatar in 2016 as RR Global, producing a wide range of premium cables for the infrastructural, industrial, commercial and residential segments with safety and fire requirements in mind.

All the sessions were well appreciated by the participants and there were good interactions on them. Mr. B Ravindranath, Head of Operations, Domestic Projects Group, Voltas Limited graced the occasion.

The speakers from CEAI and some of the participants were taken on a brief tour of the exhibition by the WorldBuild India team. They interacted with the staff

managing the stalls and learnt of the new products being manufactured and introduced into the market by the exhibitors.

The vote of thanks was proposed by Mr. Jeffrey Nambiar, Hon. Secretary & Treasurer, CEAI-WRC who made sure that the programme kept on track.

He succinctly summed up each of the 11 presentations covering various facets of engineering for the built environment.

He individually thanked each speaker and highlighted the essence of each presentation as follows:

Mr. A P Mull, Former Managing Director, Tata Consulting Engineers Ltd. & Past President CEAI dealt on “*Advances in Building Materials*”. He brought out awareness in nano materials like Graphene and its stronger version Carbyne, bendable concrete ConFlex, et al. Mr. Mull also propounded an excellent shibboleth i.e. to be “*Master Engineers*” by being objectively oriented.

Mr. B B Gharat, Technology Principal, Tata Consulting Engineers Ltd. spoke about the “*Advances in Civil Engineering*” covering BIM (Building Information Model) 5D concepts to design, schedule and budget with improved constructability. He also covered various mechanization methods as well as 3D concrete printing concepts, in construction.

Mr. Sridhar Nidamarty, General Manager and Head, MEP Business (Buildings and Industrial), Voltas Limited covered the “*Advances in HVAC*” highlighting 30 to 40 % saving in energy by reducing the AHU power requirement, using the “Chilled Beam” and ‘Radiant Cooling’ concepts that they have recently implemented in large projects.

Mr. Sanjay Thanki, Head - Water Management Business, Domestic Projects Group, Voltas Limited focused on “*Advances in Water & Waste Water Systems*” covering case studies in large projects for Water and Waste water management. He showed how substantial savings in domestic excesses can be brought about by a mobile based app and a “Water Watcher” flow measurement device.

Mr. Balachandran Dharman, Director, R R Global demonstrated the manufacturing excellence, certification of their products and showcased the “*LSOH Flame retardant cable*” ideally suited for commercial buildings and residences.

Mr. Swapnil Joshi, Founder, Intento Associates demonstrated “*Project Management tools in Engineering Contracts*” He successfully showed the benefits of good Project Management using tools like Prima Vera coupled with continuous monitoring and reporting by means of detailed schedules for planning the execution, billing, etc. which have enabled substantial saving in resources, time and money for large infrastructure projects. He brought into focus a mobile based app that could provide real time update on PMC activities for upper management perusal. The app also records the location from where the entries are made.

Ms. Anandi Khandekar, Regional Director-South, TAK Consulting Pvt. Ltd. explained the development in the presentation on “*Advances in People Moving Systems*” and projected the state of the art people moving systems like TWIN (2 cabs in 1 shaft) and Double Deck elevators.

Mr. V V Barve, DH Electrical, Tata Consulting Engineers Ltd. spoke about “*Advances in Electrical Systems & Lighting*” covering a very vast subject on Smart Grids/ Smart Controls and systems to bring about reduction in losses, improved efficiencies, energy and cost savings. He also covered the advances in non-conventional energy generation systems.

Mr. Arup Barat, Migration & Key Accounts Manager, Building Technologies Division, Siemens Ltd. covered the “*Advances in Building Automation and Building Information Management Systems*”. He reinforced the BIM concept for Smart Building systems eventually resulting in energy efficiency, safety and security.

“*HAZOP and SIL Studies - an Overview*” were explained by two speakers. Mr. Prakash Purandare from Chempro covered the difficult topic of *HAZOP* in a simple statement i.e. “think negatively” to assess the worst case scenarios in order to mitigate hazards while carrying out HAZOP studies for Chemical plants.

Mr. Rajgopal Krishnan covered the subject of *SIL* to assess the layers of protection for a process plant with an instrumentation system, determine appropriate Safety Levels by analyzing the instrument failure on demand and provision of additional redundancy, as per the integrity required by that level.

Mr. Rajesh Burase, Senior Sales Manager, CADMATIC presented on “*Modelling for Chemical and Allied Manufacturing Plants*” and the benefits that accrue from 3D modeling.

Mr. Jeffrey Nambiar thanked the organizers of World Build India for the hospitality and the excellent infrastructure provided with continuous attendance of the Seminar Team throughout the deliberations.

Last but not in the least Mr. Nambiar thanked the participants from the various industries and technical institutions for spending the whole day and invited the audience to become members of CEAI to assist in dissemination of engineering knowledge to a wider audience base as well as other states and to look after the interests of the engineering fraternity.

The seminar ended with gratitude from delegates, speakers and organizers to promulgate furtherance of such events on a larger scale.

Visuals of the one day conference on the theme “*Engineering for State-of-the-Art Built Environment*” was held on 21st April 2017 are presented below.



Mr. Uttam Sengupta welcoming delegates



Mr. A P Mull - Advances in Building Materials



Mr. B B Gharat - Advances in Civil Engineering



Mr. Sridhar Nidamarty - Advances in HVAC



Mr. Sanjay Thanki - Advances in Water & Waste Water Systems



Mr. Swapnil Joshi - Project Management Tools in Engineering Contracts



Ms. Anandi Khandekar – Advances in People Moving Systems



Mr. V V Barve - Advances in Electrical Systems & Lighting Systems



Mr. Arup Barat – Advances in Building Automation & Building Information Management Systems



Mr. Prakash Purandare - HAZOP



Mr. Rajgopal Krishnan - SIL



Mr. Rajesh Burase - Modelling for Chemical and Allied Manufacturing Plants



Mr. Jeffrey Nambiar giving the Vote of Thanks



Some Speakers & Delegates



View of Audience



View of Audience

FIDIC TRAINING COURSES ON PRACTICAL USE OF THE FIDIC CONDITIONS OF CONTRACTS

CEAI successfully organised Training Courses on "Practical Use of the FIDIC Conditions of Contracts" on 30-31 May 2017 at Bengaluru and 1-2 June 2017 at Chennai. The attendance at both the venues were very good.

Senior officers from Government Departments, public/private sector consultancy organisations, Construction firms and other agencies attended the training program. Some of the organisations were the Indian Navy, Ministry of Defence, Office of DG Works, Rail Land Development Authority, WAPCOS, GAIL India, GMR, IIT Hyderabad, Seabird, various Port sector companies, TCE, Voltas, CDM Smith, AECOM, COWI, ESSAR, KMC Group, etc.



Mr. Srikumar Ghosh and Mr. Malith S Mendis during the Inaugural function at Bangalore



Mr. Sri Kumar Ghosh delivering Welcome Address



Training in progress

The training was conducted by Mr. Malith S. Mendis from Sri Lanka, an accredited FIDIC Trainer and FIDIC trained Adjudicator. He is a member of the Dispute Resolution Board and Country Representative in Dispute Resolution Board Foundation. In addition, he is a Fellow and Member of many committees in Sri Lanka, UK and USA. He has held many Honorary positions as President and Chairman in various associations and was immediate Past President of Association of Consulting Engineers, Sri Lanka.

The two day training course was aimed at providing a broad insight into Project Contracting Strategy, Key Areas for Management of Projects, Financial Aspects, Risks, Claims and Management of Disputes as per FIDIC documents.

Feedback from the participants was very encouraging and they requested CEAI to conduct such training courses, covering other Conditions of Contract in the near future too.

WEBINAR PRESENTATION ON “EARTHQUAKE RESISTANT DESIGN OF BRIDGES IN INDIA”

The Young Professional Forum of CEAI organised a webinar presentation on “*Earthquake Resistant Design of Bridges in India - Current Practice and Future Scenario*” on 15 May 2017. The Webinar was meant for young and middle level practising engineers, who could understand the fundamental concepts behind the codal recommendations.



View of Participants

The lecture was given by Mr. Alok Bhowmick, Member of CEAI GC, who has 36 years of rich and relevant experience and has worked on techno economic feasibility studies, design and construction supervision of riverbridges, flyovers, Metro Viaduct and Stations, underpasses, aqueducts, industrial structures and other structural engineering works.

Participants from across India and some from other countries like *Malaysia, Thailand, Philippines* also took part.

SAROKAR SHOW BY RAJYA SABHA TV

Rajya Sabha TV organised a flagship live audience based show “*Sarokar*” on 27 May 2017 at 2.00 p.m.

They invited CEAI to participate in the program. Mr. Sudhir Dhawan, immediate Past President, CEAI represented CEAI and participated in the deliberations.

The Youtube link of the program is given below for your information. <https://www.youtube.com/watch?v=VO3jZKICQGI>

TWO DAY COURSE ON GST

In view of the GST proposed for implementation with effect from 01 July 2017, CEAI organized a two-day Course on “*Goods & Service Tax (GST)*” on 5th and 6th June 2017 at CEAI Centre, New Delhi.

A number of staff from the department of Finance/ Tax/ Accounts of our member organizations attended the course.



Mr. Gaurav Garg, CA

Mr. Gaurav Garg, CA, conducted the course and he mainly focused on the following topics

- The Concept of New Law
- Supply & Nature of Supply
- Interstate & Intrastate
- Valuation & Rates of Tax
- Payment of Tax
- Input Tax Credit (ITC) and ISD
- Registration, Returns, Assessment & Refunds
- Transitory Issues and Way Forward

CEAI ANNUAL AWARDS 2017

Engineering consultancy plays a major role in the process of development of a nation. To recognise and promote the engineering consultancy profession, the Consulting Engineers Association of India has instituted the following *National Awards for Excellence in Engineering Consultancy Services for the year 2017-18*:

- 1) Awards for Excellence in Engineering Consultancy Services and Project Engineering –Organisations in each of the following categories:

- Category a) Excellence in Project Engineering
- Category b) Excellence in Innovation Engineering

The Awards would be given separately for small to big firms. The firms would be defined on the following basis

- a) Small Firm <Rs 10 crore average turnover for the previous three years



A view of participants

- b) Medium Firms > Rs 10 crores less than or equal to Rs 50 crores for the previous three years
 - c) Big firms >Rs 50 crore average turnover for the previous three years
- 2) Achievement Awards for individuals:
 - Category a) Excellence in Project Engineering
 - Category b) Excellence in Innovation Engineering
 - 3) Lifetime Achievement Award for Individual

An official announcement about the Awards will be made soon with all the details.

FIDIC NEWS

FIDIC- ASPAC EXECUTIVE COMMITTEE

Mr.Liu Luobing, Chairman, FIDIC Member Associations in the Asia Pacific Regions (ASPAC) invited nomination from CEAI for the ASPAC Executive Committee election 2017.

CEAI Governing Council has nominated Mr.Sudhir Dhawan, Past President and Chairman of Presidents' Council of CEAI for the forthcoming election of ASPAC Executive Committee.

The results will be declared during the ASPAC General Assembly Meeting (GAM) in conjunction with the FIDIC Conference in Jakarta in October 2017.

FIDIC INTERNATIONAL INFRASTRUCTURE CONFERENCE 2017

FIDIC International Infrastructure Conference 2017 will be held from 1st to 3rd October 2017 at Jakarta, Indonesia. The conference will provide a platform to evaluate and discuss our understanding of what constitutes resilient infrastructure. In the wake of increasing natural disasters, infrastructure programmes are being implemented in some countries, but without properly understanding resilience. Predicting the effects of climate change is becoming more challenging. To ensure that our design and construction standards are robust enough, the ability to adapt is critical - from planning, design, and implementation, up to the maintenance phase.

The themes of the Conference are:

Day 1: Resilient Infrastructure

- Plenary 1 : Resilient Infrastructure – What Constitutes Resilience?
- Plenary 2 : Infrastructure Needs, Benefits and Investment
- Plenary 3 : Modelling and Digital Technology in Planning for Resilience
- Plenary 4 : Strategies, Planning, Sustainability and Resilience

Day 2 : What Do We Need to Change

- Plenary 5 : Disaster Risk Mitigation Strategies
- Plenary 6 : Resilience and Disaster Risk Mitigation in Projects
- Plenary 7 : Designing Resilient Infrastructure
- Plenary 8 : Effective Consulting Services to Support Resilient

Registration fees

(All fees are in US dollars)

CATEGORIES	REGISTRATION CRITERIA	EARLY BIRD Until 30 th of June 2017	STANDARD From the 1 st July 2017	ON-SITE From the 1 st of October 2017
FULL CONFERENCE REGISTRATION (Sessions + Social Events- Gala Dinner and Welcome Reception)				
FIDIC Member	Member of a FIDIC Member Association, Associate, or an Affiliate member. Full conference registration allows access to conference sessions from Sunday, 1 st of October to Tuesday, 3 rd of October, and includes official social events (Welcome Reception, Opening Ceremony and Gala Dinner). Includes all lunches and coffee breaks.	1050	1200	1380
Non-Member	Full conference registration for non-members: Non-Member registration allows access to conference sessions from Sunday, 1 st of October to Tuesday, 3 rd of October, and includes the official social events (Welcome Reception, Opening Ceremony and Gala Dinner). Includes all lunches and coffee breaks.	1200	1380	1580
Young Professional (YP)	YPs must be consulting engineering professionals working in a FIDIC member firm and under the age of 40 at the time of the conference. Copy of passport or ID will be requested. The YP registration allows access to conference sessions from Sunday, 1 st of October to Tuesday, 3 rd of October, and includes the official social events (Welcome Reception, Opening Ceremony and Gala Dinner). Includes all lunches and coffee breaks.	900	1050	1200

FIDIC-ICC INTERNATIONAL CONSTRUCTION CONFERENCE IN NEW DELHI 28-29-30 JUNE 2017

FIDIC in association with International Court of Arbitration (ICC) is organising a Conference on “*International Construction Contract and Dispute Resolution*” in New Delhi on 29 - 30 June 2017.

FIDIC has offered a special discount for early bird registration upto 23 April 2017. The discounted fee is Euro 545 instead of Euro 820 including 15% Indian taxes which means a saving of Euro 275/ person **This discount has been extended for CEAI members upto 23rd June 2017.** The fee applicable for CEAI members for attending the Conference is Euro 545 which inclusive of 15% tax.

A pre-conference Workshop is also organised for participants who want to take advantage of a special programme giving an overview of FIDIC Contracts, Claims Management and DAB as a prelude to the interesting topics that will be discussed during the two intensive conference days. The Workshop will take place on Wednesday 28 June and also offers a special discount of 50% to Young Professionals up to 35 years of age.

Special conditions will also apply to the combined **Conference + Workshop** which would equally enjoy the Early Bird price up to 23rd June (EARLY BIRD rate of Euro 895.00 instead of Euro 1170.00 for both Conference and Workshop).

Members should register online through the FIDIC website the normal way by ending the registration choosing “Payment by Bank Transfer”. Once the registration is received, FIDIC will ask CEAI for approval that the registrants are CEAI paid-up members. A new invoice would thereafter be generated and sent to the member for payment.

This event will be of great interest to CEAI members as it has the advantage of high level speakers at a programme tailored by distinguished experts in international construction contracts management.

The link to FIDIC website is: <http://fidic.org/events/fidiccc-conference-new-delhi-india-29-30-june-2017>.

OTHER NEWS, VIEWS & NOTES

ACCE(I) -MEGH STEELS AWARD 2017 TO MEHRO CONSULTANTS

Mehro Consultants has won award instituted by the Association of Consulting Civil Engineers (India), ACCE(I)-MEGH STEELS AWARD 2017 for Excellence in the use of hollow steel sections in Steel Structures for “*Chandigarh International Airport Mohali, Punjab*”.



The Award was given to Mr. S. C. Mehrotra and Ms. Sakshi Mehra of Mehro Consultants during ‘ACCE(I) Foundation Day cum Awards 2017’ held at Hyderabad on 29th April 2017.

FIEO 'NORTHERN REGION EXPORT EXCELLENT AWARD' TO ICT

ICT was awarded with a Gold Trophy and a Citation for “*Northern Region Export Excellent Award*” by the Federation of Indian Export Organisations, on 30 March 2017. This is a third instance, when ICT’s contributions towards outstanding Export Performance as a Consultancy Service Provider have been duly acknowledged.



Mr. K K Kapila, CMD, ICT Pvt Ltd receiving the Award

VIEWPOINT

The next issue of the View Point will be published in **September 2017** and will be dedicated to **Engineering Education in India**.

Considering the challenges being faced by Human Resource Departments across companies and experience amongst members, we would be happy to receive articles on the above theme. Authors could share their views, practical difficulties experienced and suggest solutions. Photographs may be added in the articles for better appreciation of the issues encountered and addressed. The articles for the September 2017 issue of VIEWPOINT need to reach CEAI by 31st August 2017. Articles need to be in Times New Roman 12 with single line spacing.

ADVERTISEMENT IN VIEW POINT

VIEW POINT is circulated to all CEAI Members, Government Offices, Public & Private Sector Undertakings, Construction Firms, Contractors, Consultants, Foreign missions and Funding Institutions in India and others organisations related to or dealing with the engineering profession.

In order to encourage members and others, CEAI offers attractive advertisement tariffs.

The advertisement tariff per issue is given below:

ADVERTISEMENT TARIFF

Rate: Back Cover	-	Rs. 20,000/-
Inside Front Cover	-	Rs. 10,000/-
Inside Back Cover	-	Rs. 10,000/-
Full Page	-	Rs. 7,500/-
Service Tax @ 15% extra / as applicable		

**In case the advertisement is to be inserted in consecutive four or more issues of View Point, a rebate of 20% will be admissible.*

DEDICATED FREIGHT CORRIDORS TO BE COMMISSIONED BY 2018. According to Adesh Sharma, Managing Director of DFCCIL after years of delay, work on the Rs 81,000-crore dedicated freight corridor (DFC) project, India's ambitious attempt to reform freight transport, has picked up pace in May 2015. With most land and funding requirement tied-up, Dedicated Freight Corridor Corporation of India (DFCCIL) is confident of starting phased commissioning from 2018.

http://www.business-standard.com/article/economy-policy/dedicated-freight-corridors-to-be-commissioned-by-2018-adesh-sharma-115051900525_1.html

Tech Quiz

1. In which state of India is the longest road bridge located?
 - A. Bihar
 - B. West Bengal
 - C. Assam
2. In which city did the world's first underground railway start?
 - A. New York
 - B. London
 - C. Tokyo
 - D. Moscow
3. What is the cheapest and oldest mode of transport?
 - A. Land Transport
 - B. Water Transport
 - C. Air Transport
4. In how many days was a new bridge constructed on the River Savitri in Maharashtra?
 - A. 255 days
 - B. 165 days
 - C. 345 days
5. Which state in India will have the world's highest railway bridge?
 - A. Himachal Pradesh
 - B. Uttaranchal
 - C. Jammu and Kashmir
6. Which country has the world's biggest road network?
 - A. China
 - B. India
 - C. USA
 - D. Russia
7. Which country has the world's longest rail network?
 - A. Russia
 - B. India
 - C. China
 - D. USA
8. What is the fictional teleportation machine used in the 'STAR TREK' Universe?
 - A. Transducer
 - B. Transporter
 - C. Star Fleet
 - D. Wrap Driver
9. To take us beyond our planet, which Apollo mission was the first manned mission to land on the moon in July 1969?
 - A. Apollo 10
 - B. Apollo 11
 - C. Apollo 12
 - D. Apollo 13

Answers to Tech Quiz March 2017 issue:

1-c); 2-b); 3-a)&c); 4-d); 5-a)

Arghya Adhikari of STUP is the winner of the Tech Quiz with the maximum points.

STUP, established in 1963, an Indo-French organization of international repute which provides design, construction engineering, technology transfer and project management services for multiple sectors.



Sectors

01. Airports & Aviation
02. Environmental and Public Health Engineering
03. Energy, Telecommunication and Space Infrastructure
04. Roads, Highways, Expressways
05. Urban, Rural and Industrial Development including all Types of Buildings
06. Bridges & Flyovers
07. Railways
08. Offshore, Harbour and Coastal Engineering
09. Metros
10. Water Resources and Agricultural Development
11. Construction Engineering, Project Management and Technology Transfer
12. Rehabilitation of Structures and Heritage Buildings



Regd. Office: 1004 & 5, Raheja Chambers, 213, Nariman Point, Mumbai - 400021, India. Tel: +91 22 40868686 Fax: +91 22 22048424
 email: mumbai@stupmail.com web: www.stupco.com

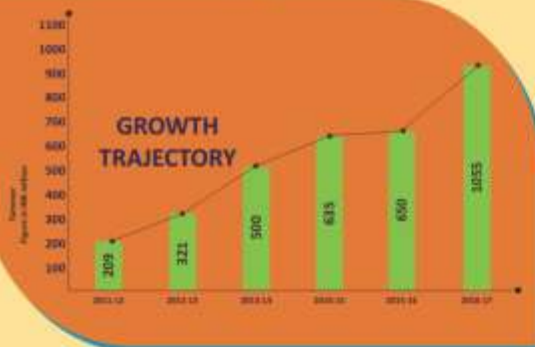
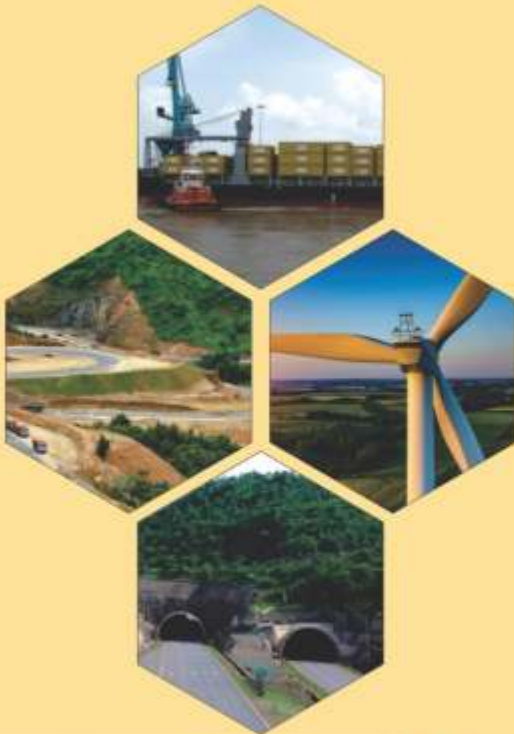
• Los Angeles • Paris • Ahmedabad • Bengaluru • Chennai • Guwahati • Hyderabad • Kolkata • Mumbai • Navi Mumbai • New Delhi • Pune
 • Port Louis • Muscat • Dhaka • Baghdad

“Build Together, A Better World”

Rodic Consultants Private Limited - a name which spells excellence and inspires confidence - was established in the year 2000 with a vision to provide a spectrum of consulting services in the field of infrastructure. Over the last fifteen years, it has emerged as a strong, motivated and sound organisation that has time and again proven its core competence in providing expertise in the sectors of Highways, Bridges, Tunnels, Railways, Rodic has also made inroads into Hydropower, Power - T&D, Inland Waterways, Water Resources and Urban Development sectors.

Certified with an ISO9001:2008, ISO14001:2004, OHSAS 18001:2007 and TRACE certification. Rodic has moved from strength to strength in its quest for excellence. Our confidence has further grown by being associated with projects involving major funding institutions such as The World Bank and The Asian Development Bank, the Government of India. We have a strong Pan-India client base, whose confidence and trust we have earned with our exemplary expertise in the areas of Consulting and Engineering, Advisory Services, Feasibility Studies, Detailed Engineering, Proof Checking, Value Engineering, Detailed Design, Detailed Project Report Preparation, Construction Supervision, Owner's Engineer and Project Management.

Our strength lies in the value of sincerity and hardwork that our Company upholds. We are further enriched by the more than six hundred skilled and motivated professionals who work with us in a spirit of team-work and productive co-operation. A continuous striving for excellence has always been our Mantra and we lay a high premium on commitment and client satisfaction. Our Value-system encompasses - competence, innovation, client-centric approach and delivering within time frames.



AWARDS AND RECOGNITION'S

- Achievers Award 2015 conferred on Mr. Raj Kumar, Chairman and Managing Director, for successfully achieving milestones in the implementation of the AIIMS - Digha Elevated Corridor by the Hon'ble Chief Minister of Bihar Shri Nitish Kumar, on the occasion of 6th foundation day of BSRDCL.
- Rodic Consultants Pvt. Ltd. was featured in "Leading SME's of India" published by Dun and Bradstreet.

JOB OPENINGS

We are also looking for qualified and experienced professionals from relevant disciplines to join Rodic family for our various current and upcoming projects on a Pan India basis. Interested candidates are encouraged to forward profiles by email to career@rodicconsultants.com

RODIC CONSULTANTS PRIVATE LIMITED

CORPORATE OFFICE :

Till July 2017

4th Floor, Tower A,
DLF Cyber Greens, DLF Cyber City,
Gurgaon - 122 002, Haryana, (INDIA)
t: +91 124 4539030
f: +91 124 4539031
e: contact@rodicconsultants.com
w: www.rodicconsultants.com

After July 2017

Cultural Center Cum Library Building
1st Floor
Jai Singh Road
New Delhi 110001

