Career Profile of

Mr. Bojji Rajaram
Managing Director, Konkan Railway Corporation Ltd

Recipient of S.B. Joshi Memorial Award for Bridge & Structural Engineering for the year 2004, cited by Alumni Association of College of Engineering, Pune

Date of Birth:

- 1st Feb, 1945

Educational Qualification and Training:

- BE, Civil (Hons), Andhra University - 1996
- M.Tech (Structural Engg), IIT, Kharagpur -1968
- Diploma in Management / Construction, British Council, UK – 1984

Profesional Experience and Achievements:

- Since 15-12-97 MD & CEO Konkan Railway Corporation Ltd., (Schedule A Group, Govt of India appointment)
- 1993-97 Director (Projects) Konkan Railway (Schedule B Grade)
- 1990-93 Chief Engineer Panaji Goa – Konkan Railway
  Responsible for the US $ 1 Bil. BOT Construction Project of
  Konkan Railway involving 90 tunnels, more than 2000 bridges
  covering length of 760 Km : praised as an engineering marvel
  and BBC said " west can only envy" the performance!
- 1987-90 Design Engineer, Zambia Railway Zambia
- 1983 Consultant to Aquaba Railway Corporation, Jordan, on Track Vehicle Interaction
- 1978-87 Joint Director Research RDSO Lucknow – Research & Evolving norms incl. Metro Systems/ Management of Research & Development
- 1978-79 Deputy Director Research RDSO, Lucknow
- 1970-78 Asst. / Divisional Engineer, SC Railway
- 1970 Joined Indian Railway Service of Engineers

Current Technology Projects initiated:

- Self-Stabilising Tracks’
- Raksha Kavach’ – Safety shield to prevent collisions on Indian Railways
- Moving Block System – Auto Driving Device based on ‘Anti Collision Device’
- Satdham’ – A revolutionary technology break-through for train control at stations and improved safety.
- ‘Sky Bus Metro’ – a new urban transport solution**:** At quarter the cost of current technological solutions, this proves a bonanza for urban transport providers, which not only moves people but containers too. Requiring almost no urban land and being noise-free and with no emissions re-defines lifestyle of urbanites, promising virtually free comfortable travel with less than a minute’s waiting time. Will cause paradigm shift for urban transport in the new millennium.

Publications:

- 10 papers in journal –Permanent way Institution, India
- 4 papers in Rail International, Brussels between 1983 to 1986
- 1 paper in international journal of remote sensing in 2001
- Presented papers in number of International Conferences on Bridges.

Honors, Awards, Patents

- Three National Medal from Institution of Permanent Way Engineers (India)
- Award from Council of occupational Safety,Health & Environment for ‘2001‘Development of Anti Collision Device’

Patents: granted

- Indian Patent for ‘Resilient Clip'
- Indian Patent for ‘Toe load measuring Device'
- Two Indian Patent for ‘RAMTRAK system (microprocessor based)'
- Resilient Clip - patents in United States of America, United Kingdom, Australia, Bangladesh
- Anti Collision Device ‘Raksha Kavach’ Patent
- Satdham Safety System - An Intelligent Signalling and Transport System
  Self Stabilising Track Patent

Affiliation with Professional Bodies:

- Fellow of the IEI, IPWE, Member of IRT (India), CSI, IMA, etc

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10 Konkan Railway Technologies For A Paradigm Shift In Rail-Guided Transport

Er. B. Rajaram
Managing Director,
Konkan Railway Corporation Ltd

10.1 Introduction

Engineers must get out of their current mould of constricted thinking to limit themselves to merely design an engineering component, to become just a cog in the wheel of infrastructure development. A holistic view to positively take the world to the next generation of thinking, through technology to improve quality of life at reducing costs, should be the cardinal principle for engineers.

As a fellow Structural Engineer, the author has shared his rich knowledge and experience to showcase his efforts in this direction, to set an example by practice, rather than words. Development of 'Anti-Collision Device (ACD) and 'Sky Bus Metro' is the significant contribution in the urban transport Technology for the new millennium.

The Indian railways have seen 150 years of railway working and now to pitchfork into the next generation of rail guided system. Time has come to quickly cause and implement technology break through to effect (a) safer, reliable and improved quality of service, (b) reduced cost through improved productivity and improved benefit to cost ratio for the investments leading to maintenance free systems. The pace of technology development and absorption by implementation is not encouraged by the current administrative structure, causing the Government railway a drifting organization.

The advent of an independent Konkan Railway, created by the Railway Ministry, first time in history allowed an opportunity to try alternate model of railway working and development of rail-based technologies.

The author has developed several technologies such as innovative management methods, novel technical solutions for conventional railways and rail-based next generation innovations. These are outlined initially in the chapter.

Anti-Collision Device (ACD),named as a 'Raksha Kavach', and Sky Bus Metro are the major Inventions developed and patented by the author. Technical details of these technologies are briefly explained in the chapter.

The economics of some pilot projects is also illustrated for future National Developments.

10.2 Innovative Concepts for Different Technologies

The Konkan Railway Corporation Limited, India (KRCL) has developed the following technologies in the short period of its existence of 5 years as an open railway line since 1998.

10.2.1 Railway Application Package (RAP)

Innovative Management methods are introduced for real time operation &train control, asset-management of track, rolling-stock, signal/telecommunications, electrical, health care, medical and personnel , distance education & training, security; covering all the departments of railways. RAP –a unique Railway Applications package covering all aspects of railway management resulted to the superior operational performance of the Konkan Railway. RAP received kudos from the World Bank!

10.2.2 Technology Solutions for Conventional Railways

(a) Track & Civil engineering

- Boulder nets-special steel type
- Tunnels & cuttings inspection and maintenance-special logical scientific procedures
- Flexible flowing structures-economic platform structures
- Self Stabilizing Tracks (SST)

(b) Track-Vehicle Interaction-Dynamic Loads/ Health of Rolling Stock and Track

- ROSHAN: on line real time health assessment and reporting for the rolling stock at wheel and suspension levels
- On line real time reporting for the track- vehicle interaction service limits for guided track maintenance through networked ACD and mounted accelerometers “Track Vehicle Safety Monitor” TRAVELSAFE system.

(c) Safe and Improved Train Control and Station Management

- **ACD Ver 1.0 :** Anti Collision Device- a microprocessor based ***nonsignal*** equipment with embedded knowledge network with other ACDs to prevent disastrous collisions involving human lives.
- **Satdham Safety Systems**: stations are made intelligent and automatic to safely handle receipt and dispatch of trains, first time providing positive interlocking between the route and the train using the ACD devices. The current signals and track circuits will become obsolete.
- **Moving Block Systems**: The ACDs mounted on the trains implement intelligent control with each other as they move on the track, to provide a safe distance required to brake and stop – providing a variable moving block over the existing lines, enhancing capacity 3 fold.
- **Real-time global information system**: By combining with the RAP the Moving Block System and Satdham Safety System will give a real time information system to operators as well as the customers.

10.2.3 Rail-Based Next Generation Technologies

(a) Sky Bus Metro: Causes a paradigm shift in providing economic and financially viable futuristic, faster & safer urban transport without the ill effects of previous generation elevated and underground metros. Additionally being capable of handling containers or RO-RO service, truck movement in urban areas get either eliminated or virtually non-existent. Time of construction is compressed to within two years! The capital cost is cut down by more than half to 3/4th!

(b) Sky Rail: In very treacherous hilly terrain can provide economic and safe rail transport of high speed, giving flexibility to designers to adopt 1:1 gradient and minimum radius of curvature of 15 m! Can handle the heaviest of army loads! Can be set up quickly within two years!

(c) Sky Con: An improved rail based system to handle in an integrated manner the entire port operations. The system provides for unloading and loading of containers and general goods in ships at 5 to 10 times the current available best system. Also all issues of inter modal transfers are handled in an integrated manner between the rail/road and ship, causing a paradigm shift in port design and operations.

(d) Sky Jet Service: High speed 200 kmph safer inter-city travel with average speeds of 180 kmph- bringing all major metropolises within 8 hours of journeys at affordable prices- as the same lines can deliver cargo too,unlike existing high speed tracks in the world.

10.2.4 Intellectual Property– Protection

Patents:

All the Patents are in name of the author as Inventor and stand assigned to President of India**.**

- Sky bus Metro -A Novel Suspended Coach Transportation System

  Five Patent Applications

  1. Sky Bus Metro- No 715/MUM/01
  2. Swing Arrester- No 716/MUM/01
  3. Derailment Arrester- No 717/MUM/01
  4. Collision Arrester- No 718/MUM/01
  5. Suspender- No 719/MUM/01

- Anti Collision Device –
  Patent Application No 668/BOM/99 dated 24.9.1999

10.2.5 The Total Business Opportunity to The Konkan Railway

It is estimated at current prices to be about Rs 100000 cr for all the above technologies, on a conservative basis. Being a public purpose serving company, even at modest royalty-fees of 10%, this converts as an earning of Rs 10000 cr to the Konkan Railway. Over next decade this can be realized, provided we quickly allow ourselves to implement and demonstrate pilot projects in each of the above areas.

The knowledge- based systems will reinforce our country's position as an economic superpower to improve quality of life through technology of the new millennium and gives boost to our own industrial production in core sectors on a sustained basis.

The single one point hurdle in gaining this advantage to our country is basically the processing time to take even a simple decision. The environment currently is paralysed by excessive analysis by people at various tiers of decision making, solely designed to avoid fixing any accountability nor responsibility by avoiding or doing their best to postpone any action during their tenure.

It is necessary to ensure financial prudence and observe the simple canons of financial propriety as public funds are utilized. But once the system has set the procedure for such expenditure to be monitored, there is no need for repetitive cycles of examination without any value addition.

We must unlock value of our assets both human and infrastructure, by reorienting ourselves and take the policy initiatives. A passionate commitment is needed to place our Indian Railways in the forefront, leading in the world with cutting edge technologies, which is well within our reach, given the core knowledge base our country is built on.

10.3 ‘Raksha Kavach’- Networked Anti- Collision Device (ACD) System

10.3.1 Anti-Collision Device (ACD)

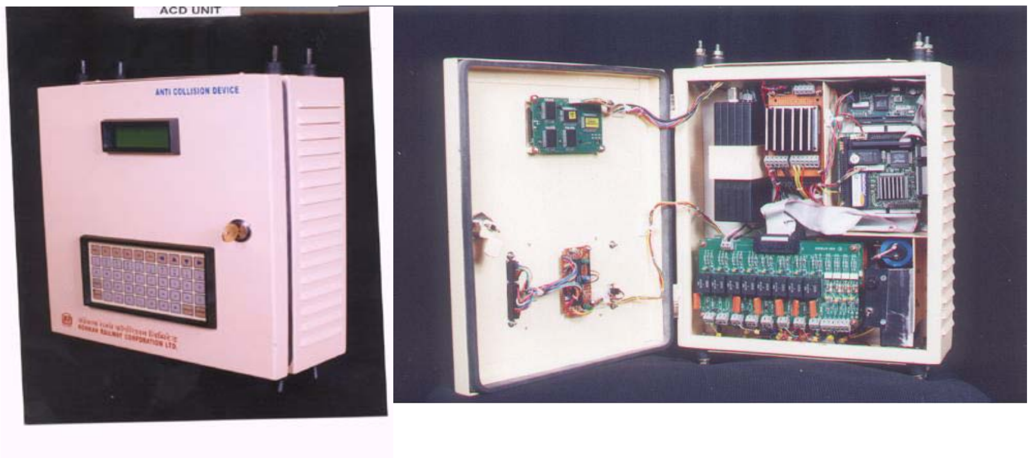


Fig 10.1 Locomotive ACD Equipment

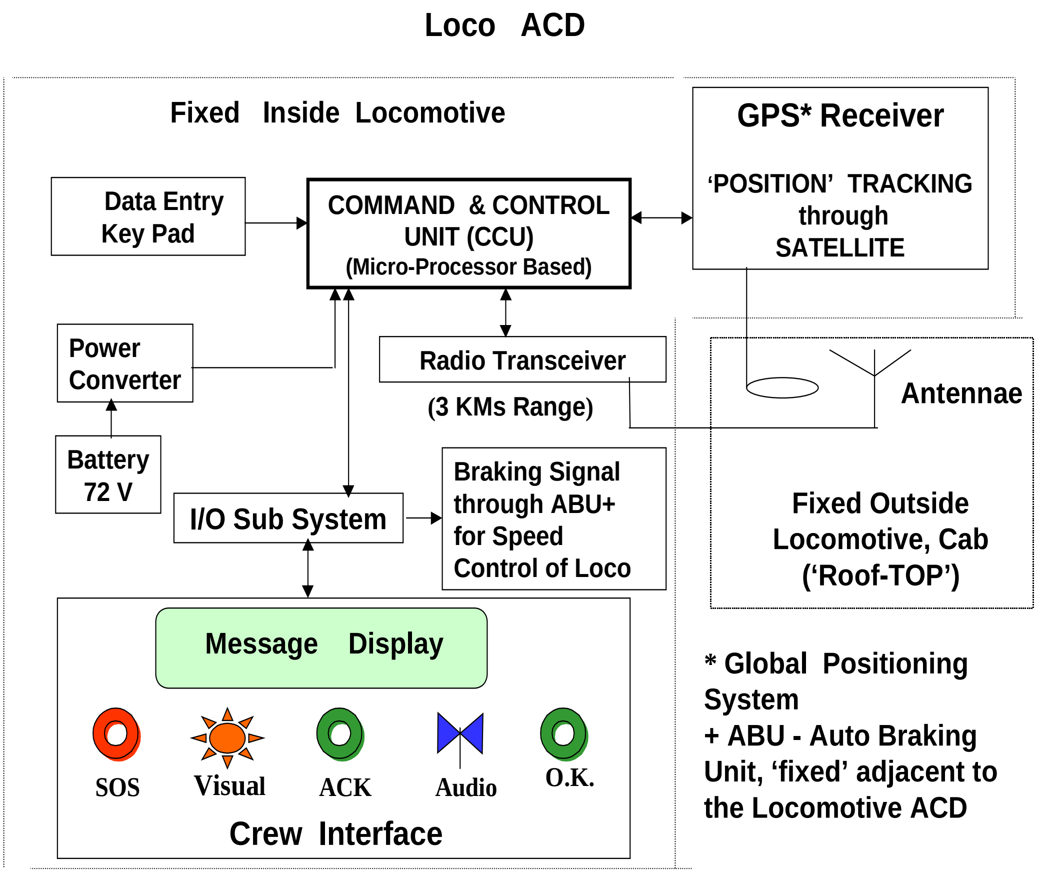


Fig.10.2 Block Diagram of Loco ACD

ACD is 'self-acting' microprocessor-based communication equipment designed and developed by Konkan Railway. ACD, as shown in *Fig.10.1 & 10.2*, mainly consists of the following Modules.

10.3.1.1 Command and Control Unit (CCU)

This Microprocessor Based Module is the heart of the ACD system. It processes the data and generates commands from the ACD.

10.3.1.2 GPS Receiver

It picks up signals from the constellation of GPS Satellites (exclusively being used for Global Positioning purpose) and submits the same to Command and Control Unit to extract the parameters related to the movement of locomotive like latitude, longitude, speed, angle, date and time. The antenna of the GPS Receiver is fitted outside, on the rooftop of the locomotive.

10.3.1.3 Crew Interface

This user-friendly interface helps the driver to know various status in the form of Audio-Visual indications and text displays, like 'Station Approach', 'SOS' (for 'Head-on' / 'Rear-end' / 'Side' Collision situations), 'Train Parted', 'Gate Open' etc. It also gives a facility to driver for pressing of 'SOS', and 'Cancel' buttons.

10.3.1.4 Data Entry Key Pad

It helps the maintenance staff to feed as well as extract information from ACD.

10.3.1.5 Radio Trans-Receiver

It transmits the information and commands being generated by its own Command and Control Unit. Similarly, it receives the information and commands being sent by other ACDs, when the same are within the radio-range of about 3 Kms. The Omni-directional antenna for the radio Trans-receiver is fitted at a convenient location on the rooftop of locomotive cab.

10.3.1.6 Braking Mechanism for Speed Control of the Locomotive

As a result of the processing of information received from other ACDs, the Command and Control Unit takes a decision for applying either the normal brake or the emergency brake on the locomotive, as the case may be. The braking is then applied through suitable solenoid interface installed for this purpose in the cab of locomotive.

10.3.2 Types of ACDs

Anti-Collision Device System is a network of different types of ACD units as follows:

Loco ACD: It is an ACD installed in Locomotive and self-propelled rail vehicle along with Auto-Braking Unit, Driver’s consoles, radio and GPS antennae, speedometer and interconnecting cables.

Guard ACD: It is a portable ACD, which can be loaded in Guard Van along with radio & GPS antennae, batteries and interconnecting cables.

Station ACD: It is an ACD installed at a location from where train operations are controlled at the station along with SM’s console, radio antenna, power supply module, battery and other accessories including need based interfacing with Signalling circuits and interconnecting cables.

Manned LC Gate ACD: It is an ACD installed at Manned Level Crossing (LC) Gate along with radio antenna, power supply module, battery, and other accessories including interfacing with devices that provide open/close position of the LC Gate and interconnecting cables.

Un-Manned LC Gate ACD: It is an ACD installed at Un-Manned Level Crossing along with radio antenna, power supply module, battery, other accessories and interconnecting cables.

ACD Repeater: It is an ACD installed along with radio antenna, power supply module, battery, other accessories and interconnecting cables at locations identified as inter-ACD communication shadow zones, for providing continuous Radio communication coverage.

Loco Shed Bahar Line ACD: It is an ACD installed at a location from where the operations are controlled in a Loco shed along with LF’s console, radio antenna, other accessories and interconnecting cables.

10.3.3 Functions of ACDs

While approaching a Station, Loco ACD gives 'Station Approach' warning to the driver, about 2 Kms in rear of first STOP Signal of the station. This warning will be audible for a fixed time of 5 seconds. The visual message on text display will be there until the Loco crosses First Stop Signal. In effect, the Loco ACD acts in this case like an 'Electronic' Signal Sighting Board.

While entering the Station Area, if Loco ACD detects the presence of a train on the main line, it 'automatically' regulates its train speed to what is maximum permitted over turnouts, thereby reducing possibility of 'high-speed' collision. Further if, Loco ACD after entering in loop line, detects presence of another train on the same track, both trains 'automatically' regulate speeds of their respective trains to avoid collision.

While travelling in the Mid-Sections, Loco ACDs remain in 'look out' for trains present in the radius of 3 Kms to handle following potentially dangerous 'collision-like' situations as follows:

- In case, Loco ACD detects that any other train has stopped on adjacent track may be due to derailment, Loco failure, cattle run-over, alarm chain-pulling etc., it will automatically regulate the speed of its train till such time it crosses it and will also warn the driver of the same. If the driver of the stopped train presses 'Cancel' button after ensuring that there is no danger to movement of trains on adjacent track, the speeds of other trains will not be regulated. However, if he detects that there is an infringement to the adjacent track and presses twin 'SOS' (Save Our Soul) buttons, the other approaching trains will come to a stop, thereby reducing possibility of either 'rear-end' or 'side' collisions

- In case, a train detects an another train approaching it on the same track, the Loco ACDs of both the trains apply brakes to bring their respective trains to bring them to a STOP, thereby reducing possibility of 'head-on' collision

- In case, a train detects an another train moving ahead of it on the same track, its Loco ACD 'automatically' applies the brakes to regulate the train speed, till such time the separation distance between the two starts 'increasing' again, thereby reducing possibility of 'rear-end' collision.

- In case, a train while approaching a level crossing gate, detects it in 'opened' condition, its Loco ACD regulates the speed of its train and warn the driver for taking appropriate action. Simultaneously, the LC gate ACD activates its hooter with visual flashing light for 'alerting' the road users, till such time Loco crosses the LC Gate, thereby reducing possibility of collision of a train with road vehicles, crossing the LC Gate

- In case, a train is approaching an un-manned level crossing gate, the LC gate ACD activates its hooter with visual flashing light for 'alerting' the road users, till such time Loco crosses the LC Gate, thereby reducing possibility of collision of a train with road vehicles, crossing the LC Gate

Drivers of the trains thereby get 'Door-drishti' (a 3 Kms range detection system in all weather conditions, which a human eye is incapable of) through their Loco ACDs to detect the presence of trains in their vicinity.

By acting 'independently', the Loco ACDs also acts like 'Saathi' for the drivers. Further, in case a 'collision-like' situation is perceived, the drivers get empowerment to stop other approaching trains by sending 'DISTRESS' messages through pressing of 'SOS' buttons, provided on their ACD consoles.

The Guard ACD detects 'train parting' and both Loco and Guard ACDs of the train radiate 'Auto-SOS' signals to prevent 'rear-end' and / or 'side' collisions of their train that might have derailed and infringing the adjacent track.

10.3.3 Raksha Kavach

Raksha Kavach is a network of different types of ACD units, namely Loco ACD, Guard ACD, Station ACD, Level Crossing Gate ACD, Loco Shed Bar Line ACD, TID Assigning ACD and Repeater ACD. Each ACD is an intelligent microprocessor based system, which uses a GPS receiver (for Loco and Guard ACDs), radio modem for communication with other ACD units and interfaces with Signalling circuits, speedometer, self-propelled vehicles and other external devices, on need basis.

Though at Stations, signals are provided for ensuring safety in train operations, any human failure of driver will be taken care of by the 'Raksha Kavach' (Anti-Collision Device System), proven to prevent collisions at 'high speeds'.

In Mid-sections where neither the protection of signals nor the guidance is available to the driver, the 'Raksha Kavach' makes the loco 'intelligent' and extends its capability to detect any 'collision-like' situations in a range of 3 Kms which driver cannot detect on his own. The examples are likelihood of any collision between two approaching trains or between a derailed train on the one track and an approaching train on the adjacent track.

In effect, 'Raksha Kavach' provides 'Door-drishti' (a 3 Kms range detection system in all weather conditions, which a human eye is incapable of), allowing the locomotive to act 'independently' to apply brakes, in case it perceives a danger of collision - a TRUE 'Saathi' for the driver.

'Raksha Kavach' in the form of a 'Silent' network of ACD systems, once provided on the locomotives, guard vans and at stations, will effectively ensure that trains will not collide at high speeds, which normally results in heavy loss of human lives. If ACD systems are provided at Level Crossing gates (both manned as well as un-manned), the extended 'Raksha Kavach' will effectively protect the lives of road users also.

The 'commercial' prototypes of ACD system have been tested over the last one-year. Konkan Railway has developed this totally indigenous and economic system first time in the world, which has been technically proven during the Extended joint field trials with RDSO (Research Design & Standards Organisation) nominated by Indian Railways.

Raksha Kavach in the form of 'Networked' ACD System also Empowers its other Users to send 'SOS' to Loco ACDs for stoppage of trains, whenever a 'collision-like' situation is perceived by them as under:

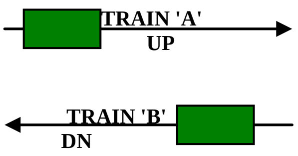
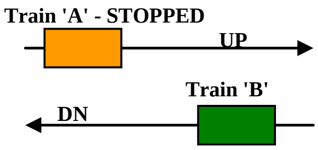
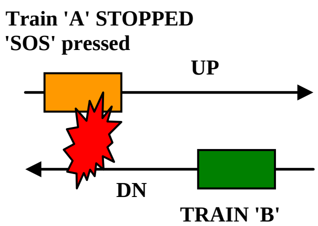
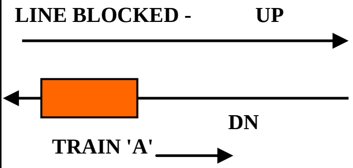
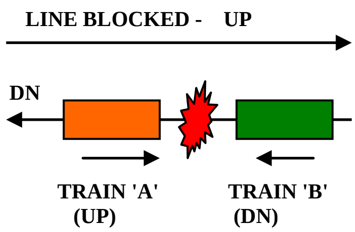
- Guard can send 'SOS' through his Guard ACD when he observes dragging of derailed coaches / wagons close to his SLR / Brake Van <u>or</u> notices a Fire in the running train

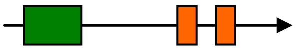
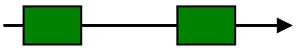
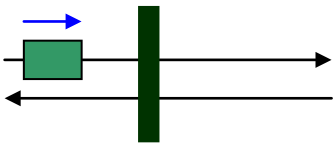
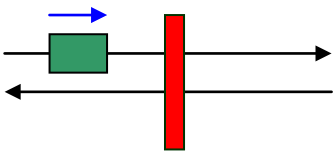
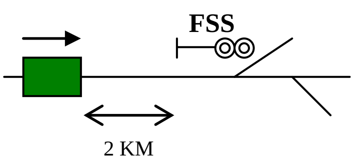
- Station Master can send 'SOS' through his Station ACD when he notices any unusual like 'hot-axle' / 'flat tyre' / 'fire' etc in a train, while performing train passing duties

10.3.5 Working of ACD System as Raksha Kavach

'Raksha Kavach' ('Networked' ACD System) developed by Konkan Railway is now being implemented on Indian Railways.

The different Scenarios are described 'pictorially', as under:

Scenario	Situation	Action by ACD
<u>1.Normal</u> 	Up Train on Up Track. Down Train on Down Track – **Both Trains Moving**	**No Action**
2. <u>One Train Stopped</u> 	Train 'A' stopped in mid-section out of way and Train 'B' is Moving on 'adjacent' track	In the absence of 'Normalcy' flag from Train 'A', ACD of Train 'B' will automatically initiate Audio-Visual Indication and apply braking to regulate the train speed till such time it fully crosses the Train 'A'
3. <u>Derailment</u> 	Train 'A' has **derailed** resulting in adjacent track may or may not getting blocked Driver/Guard of Train 'A' presses '**SOS'** button of ACD	'SOS' of Train 'A' when detected by Loco ACD of Train 'B' will automatically initiate Audio-Visual (AV) Indication and braking action to **STOP** the train **'Possibility'** of **<u>'Side' Collision Reduced</u>**
4. <u>Temporary Single Line (TSL) Working</u> 	Up line is blocked. Hence Up Train 'A' is sent on **WRONG** Track, from the Station in Rear	ACD of Up Train 'A' will permit it to run at NORMAL speed
	Now Down Train 'B' is approaching from the **Opposite direction** on its **RIGHT** Track	ACDs of both the trains will **sense the DANGER** and initiate AV indication & braking to bring their respective trains to a **STOP** - Applicable also to **Single Line Sections** **Possibility of <u>'Head-on' Collision Reduced</u>**

5. Train 'Parting'  **Train 'B' Train 'A'** **(parted)**	After 'parting', both Loco & Guard ACDs of Train 'A' are radiating 'Auto' SOS and the Train 'B' sent in the section on the same track detects the same	Loco ACD of Train 'B' will apply brakes to bring it to a STOP **Possibility of** **<u>'Rear-end' Collision Reduced</u>**
6. Train 'Following'  **Train 'B' Train 'A'** **(following)**	Train 'B' sent in the section on the same track detects Train 'A', moving ahead of it	Loco ACD of Train 'B' will apply brakes to regulate its speed in such a manner that an 'adequate' braking distance is always maintained from Train 'A'. However, it will bring Train 'B' to a STOP in case it detects that Train 'A' has already come to a STOP. **Possibility of** **<u>'Rear-end' Collision Reduced</u>**
7. Level Crossing Gate		
 **(a)** **<u>Manned</u> LC Gate 'Closed'** **OR** **<u>Un-Manned</u> LC Gate**	Train is approaching LC Gate & its 'ACD' is within the Radio-range of 'Gate ACD' **[LC Gate ACD also acts like a 'Train Actuated Warning Device' (TAWD) for the Road Users]**	**(a)** The LC Gate ACD activates **'flashing'** light & sounds **'Hooter'** for warning the Road-users when the Train is approaching the LC Gate. This AV indication will STOP automatically moment the train passes the LC Gate.
 **(b) LC Gate 'Open'** **OR** **Under Operation** **(Manned)**		**(b)** In addition to (a) above, the LC Gate ACD sends the status of LC Gate position to the Loco ACD of the approaching train, which in turn will automatically initiate braking to **regulate** the speed of train till such time it crosses the LC Gate. **Possibility of <u>Collision with the Road Vehicle trying to cross the track portion in haste, is reduced</u>**
8. Driver Alert on Station Approach		
	When Train is approaching a Station and it is about 2 Km away from its First Stop Signal (FSS)	Driver gets the Audio-Visual (AV) 'Station Approach' warning given by his Loco ACD until such time the train crosses the FSS.

10.4 Sky Bus Metro : The True Urban Transport Technology For The New Millennium!

10.4.1 Opening Remarks

The most precious asset in growing urban areas is the land. Allocation to residential and commercial purposes put heavy pressures on land for public use like parks and open spaces apart from very important and critical roadways. Hardly 6% to a maximum of 18% of land in cities form roadways. The roadways once laid- almost remain constant – at best- and may effectively reduce by uncontrolled encroachments. The physical constraint of road area being constant, as population increases, naturally loads on roads increase.

As more and more people from different habitats try to converge on to the central business district, the road has no capacity to handle and congestions erupt. Roads take one exactly to the point where one wants to go. But the capacity is limited in terms of passengers per hour that can be handled. Even if one considers only buses, need to maintain the braking distances between two buses and the space maintained between them affects speed as well as limits per lane what capacity can be achieved. When mass transit , that too at higher speed is required, rail based systems only can handle.

10.4.2 Requirements Of An Ideal Urban Transport System

Heavy concentrations of residential units coupled with required movement to work places or to market places demand transportation of people.

Roads are to cater for the same. But roads have a limitation- the area available remains constant, once the development is completed, and old cities in particular throw up the problems of mismatch of designed capacity versus the increasing pressure of populations.

Let us examine the various modes of transport that population uses in a city and their capacities and limitations, to evolve requirements of urban transport solution in a holistic manner.

Currently available solutions are either elevated railway or underground railway if mass transportation is required.

Elevated railway technically cannot reach truly congested central busy roads where the mass transport is needed. It is also too invasive and may require dislocation of some portions of habitat as well as introduces noise pollution.

Underground railway is less invasive on surface but still poses technically challenging risks of fires and evacuations. It also has to address concerns for foundations of heritage buildings.

If road vehicles are involved, in inter-modal transfers, it becomes weak link in the chain of transport between walking and railway. Both modes suffer from derailments and capsizing killing commuters.

Surface railway is impossible to lay in an existing city. But even to lay the same in a new development, one should keep in mind what happens after 50 years of laying the same. We have living example of our own suburban system. The city remains divided by the corridor and it is an eternal noise polluter in the heart of city day in and day out.

Sudden disgorging of heavy loads of commuters at stations create need less congestion on the roads, reducing quality of life. Almost close to 2000 persons die annually because of trespassing or falling from trains in our present system, whatever be the excuse and justification for accepting the same. In addition vulnerable to minor vandalism by urchins, but resulting in grievous injuries like losing sight for the commuters. Again this mode cannot follow roads, so the weak link of road vehicles has to be brought in for inter-modal transfers.

Derailments, collisions and capsizing concerns remain with loss of life for all the above mentioned three systems.

The infrastructure created for urban transport is hardly utilized to 30 to 40% capacity because of directional as well as inevitable peaks for limited hours in a day. It has no other use and just idles.

An ideal solution is one which

- Follows the existing roads- but does not take road space- and be as flexible as a bus
- Have rail based mass transit capacity, same as existing rail metro
- Does not divide city while providing integration along its alignment
- Be derailment and collision proof- with NO CAPSIZING of coaches- so that there can never be loss of life
- Be free from vandalism
- Noise free and pollution-free
- Non-invasive -requiring the least amount of scarce land space- and not come in the way of development.

Sky Bus technology as offered by Konkan Railway meets the above requirements, and helps us re-define the thinking and planning for urban transport. Sky Bus Metro is Eco-friendly MASS urban transport and it revolutionizes urban life!

10.4.3 Description of Sky Bus Metro

Heavy 52/60 kg /m rails placed at standard gauge floating in elastic medium and damped by inertia of measured mass held in a 8 m x 2m box enclosure, supported over a 1m dia. columns spaced at 15 m and located at 15 m distance from each other, in the divider space in between lanes on a road- way, at a height of 8m above road surface- provides the support and guidance for powered bogies which can run at 100 kmph, with the coach shells suspended below , carry passengers in air conditioned comfort, can follow existing road routes, while existing traffic on roads continue.

The fixed structure at 8 m height above road level is aesthetically pleasing and there is no concern of claustrophobic feeling for road users.

Fig.10.3
Schematics of Sky Bus Metro

Aesthetic and eco-friendly, the Sky Bus as shown in *Fig.10.3* can never derail, capsize nor collide- by design as well as by construction, hence is safer than existing rail-based system. At Rs 45 cr per or US$10mn/km in India, the system is noise-free and pollution-free with 18000pphpd, scalable to 72000 pphpd as required. With no signalling and having no points and crossings, it is a unique mass-transit system, which can be put up within two years in any crowded & congested city. In addition to moving people Sky Bus system can carry standard 20ft containers, boosting its capacity utilization to double that of other existing systems.

Sky Bus metro falls under tramway category, under Art 366(20) of Constitution of India, since it operates along existing roadways and within municipal limits, hence excluded from Indian railway act.

10.4.4 The components of Sky Bus Metro

- Sky way
- Sky bogies
- Sky coaches
- Sky stations
- Traverser arrangements at terminals

Fig. 10.4 Sky Way

10.4.4.1 Sky Way

- In the middle of road way pile foundations support 1 m dia column approximately 8 m high, and space at 15 m all along the roadway
- The sky way, as shown in *Fig.10.4*, consists of a concrete box structure carried over a series of piers at a height of 8 m above existing road level
- Two rails fixed with appropriate fastenings within the concrete box support and guide the sky bogie
- There are no points & crossings

10.4.4.2 Sky Bogie

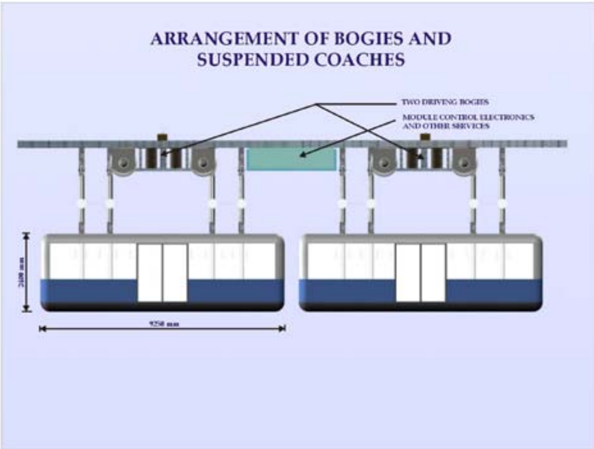


Fig. 10.5 Arrangement of Bogie and Suspended Coaches

- Standard two axle bogies as shown in *Fig. 10.5*, used in metros for speeds of 100 kmph are used (but can have higher speeds, if required up to 160 kmph)- of standard gauge .
- Linear induction motor technology is incorporated-with 4th rail driving which is above the bogie/or 3 Ph AC motors with regenerative power capability.
- Third rail is used for current collection
- Braking-bogie mounted
- Regenerative
- Disc brakes
- Emergency mechanical brakes

10.4.4.3 Design Loads

Max axle load 12 tonnes
weight of -

- Bogie - 2 axle motor: 5 t
- Tare weight of coach: 6.5 t
- Weight of equipment: 2t
- Passenger load: 9 t
- Total for a bogie: 24 t
- Axle load: 12 t

10.4.4.4 Sky Coaches

- Double walled light shells with wide large windows are suspended from the sky bogies
- Controlled banking on curves- even 100m radius curves can be handled.
- Air conditioned and with automatic doors
- Audio visual information to passengers

- Special 4m wide sliding doors for quick entry and exit of passengers
- Each pair carries 300 persons and service every one minute or 30 seconds is possible.

10.4.4.5 Sky Station

Fig. 10.6 Typical Sky Bus Station

- Unlike conventional mass transit systems, Sky Bus needs smaller stations as shown in F*ig,10.6*
- Service is every 30 seconds or 1 minute that is virtually no waiting time for passengers
- Totally automated without drivers or guards-and access control is also electronic by prepaid cards being swiped in
- Stations act as only access facility, and not as passenger holding area

10.4.4.6 Traverser

There are no points and crossings. The traverser, as shown in *Fig. 10.7*, is the system which automatically shifts the sky bus units for balancing the loads/ changing routes too as well as shift units to depot lines etc.

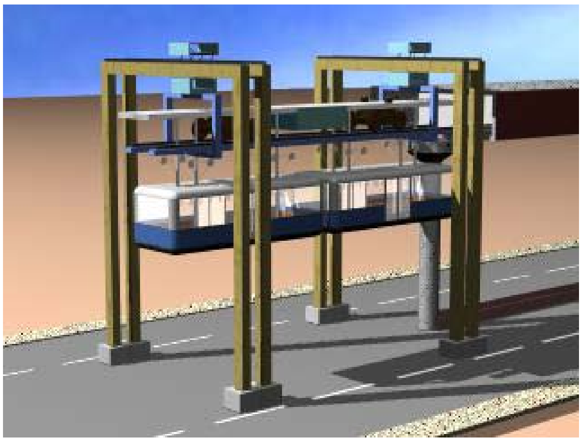


Fig. 10.7 The Traverser

Proven technologies and a very simple solution are obtained by merely re-engineering the components of Sky Bus,as given in Table 10.1.

Table 10.1 Re-engineering the Components of Sky Bus

Railway bogie running over steel rails	Proven century old technology	We daily travel!
Suspension links holding the coach below bogie	Century old suspender designs working safely	In Mono rail-systems & rubber tyred sky systems
Moving block/control	Proven micro-processor based systems	In underground metros/surface railways
Traverser	Standard mechanical handling	Existing in EOT cranes-workshops
Concrete box/columns	Standard prestressed concrete	All current structures we use today.

The new technological solution, in terms of Sky Bus Metro is based on the concept of Sky Wheels presented in 1989 at World Congress for Railway Research. The technologies used are as below

- Well proven rail guided bogie system commonly used for normal railway system.

- Linear Induction Motor Technology or 3ph AC asynchronous electrical motive units– well proven and widely adopted abroad as well as in India.

- Light weight coaches called `Sky buses' which are suspended from bogies and travel below rail guides, the physics of which can be engineered very easily – shells of coaches and suspension links well proven.

- Pre-fabricated latest construction technologies, which save time and money resulting in easy execution of the project in busy urban areas without disturbing the existing traffic pattern.. These structural engineering methods are well proven which do not have any project execution risk attached.

- Information technology tools for economic communications and control.

10.4.5 Advantages of Sky Bus Metro

- In this new technology of 'Sky Wheels', almost no land acquisition will be required, except for providing for right of way on existing roadways
- Only at terminal points, minimum amount of land of the order of 2000 to 4000 sq.m of area will be required – that too at places away from the urban centre.
- No demolition of structures or gardens will be destroyed.
- No Vandalism - Not vulnerable to persons throwing stones and track is inaccessible.
- Fire - Fastest evacuation in case of fire as compared to underground metros.
- No capsizing - If at all derails, cannot fall down coach keeps hanging. Hence no capsizing takes place as compared to railways and underground metros.

- No Deaths due to trespassing/falling off from train-In normal metros like Mumbai daily 2 to 3 deaths occur on the system with total casualties reaching almost 2000 per year.
- Reaches heart of the city - Sky Bus follows existing busy roads, thus reaches the very heart of the city decongesting the roads. This is not possible in case of Normal Railway.
- Capital cost is lowest - almost 50% of elevated systems & 25% of underground metro for same performance standards.
- Lowest running cost- Maintenance free tracks, no signals & points & crossings to maintain.
- No interference with normal road traffic- does not require road over /under bridges.
- Since the system involves guide ways in the sky, which does not fall into an exact definition of Railway, the number of agencies involved in clearing and executing the project will be minimum and only one authority at state level will be created for implementing the project.
- It can be built on roads with Fly over. It is not an impediment.
- From the date financial closure is achieved, the Project can be completed and commissioned within 100 weeks i.e. about 24 months.
- Aesthetically pleasing & no noise pollution.
- Insulated against floods, rains and obstruction on track.

This is the only metro system which can handle standard containers to move goods / services in a city – thus eliminating need for trucks to enter city areas.

10.4.6 Investments and Returns of Sky Bus Metro

Economics of Sky Bus Metro is given in Table 10.2 , 10.3 and 10.4

Table 10.2 The costs for a typical 10 km double line route

Capital			Depreciation			
Fixed structure US$ m 116			2 m for structure			
Rolling stock for pphpd		Cost	Total add for rollg stock		Total	as % of cap
A	25000	56	172	3	5	3.0%
B	50000	111	228	6	8	3.5%
C	75000	166	283	8	11	3.8%

Table 10.3 Operation & Maintenance

	Rolling stock	Fixed structure	Energy	Staff costs	Total Million $	
	5.0%	2.5%				
A	3	3	11	5	22	(a1)
B	6	3	22	6	36	(a2)
C	8	3	33	7	51	(a3)

Table 10.4 Different % of Capacity Utilisation The Min Charge			
PPHPD	20%	25%	30%
25000	5.1	4.1	3.4

50000	3.9	3.1	2.6
75000	3.5	2.8	2.3
give 10% return on capital after providing for depreciation and O&M.			

So for a charge of 2.5 to 5 cents per km or about 5 cents per mile it is possible to provide air-conditioned travel with waiting time for service at interval of less than 1 min.

A service at 100 miles per hour can be provided, if 10 miles between halts is provided.
Then a distance of 50 miles will be covered in 30 min. at a ticket charge of $ 2.50.

Ridership requirement for a viable route:
let us take case of 25000 pphpd : At least per day a minimum of 75000 commuters in one direction are required , who are expected to to return in the evening,
to make a route viable at 5 cents/km journey.

Fare box collections cover 10% return on capital and depreciation after meeting all O&M expenses.

Additional income from real estate/shopping malls/ container cargo is bonus!
Detailed survey for local area costs is required to firm up the local civil engineering costs .

The system in addition to moving people, can carry containerized cargo- thus during off-peak period also the asset is utilized. The capital cost is hardly half that of the conventional elevated railway, and only the quarter of that of underground metro- but the asset gets utilized even upto 70% of the capacity as compared to normal 30 to 40% in the dedicated urban systems. The system provides holistic solution to a city.

10.4.7 Closing Remarks

Sky Bus system not only redefines the urban mass transport for cities, but also provides for efficient auto-mated container delivery system point to point, following existing roads and brings down the cost of service while improving quality. With land being at premium, even for intra-city high speed 200 kmph system , Sky Bus provides excellent alternative for mass transport- being derailment free and safer than existing rail-based system.

Fig 10.8 Kokan Railway Corporation Limited, Sky Bus Metro

10.5 Pilot Projects with Economics for Future Development

10.5.1 Anti-Collision Device Project

The ACD project: It has taken almost 4 years since presentation of concept and only one year actually was used in actual development with technical inputs, but 3 years have gone in to administrative processing without value addition because of our administrative structure based "on no- risk mind-set". The common man traveling on trains is continuing without the protection of Raksha Kavach and of course no one can be held accountable for this avoidable delay! The system and procedures protect the decision makers, but the common man continues to be exposed to the risk of loss of life in a collision, even though we have a proven solution.

The Corporate Safety Plan of Railway envisages implementing the ACD based Raksha Kavach on Indian railways at a total cost of Rs 1600 cr. We may structure an execution plan based on BOT concept which made Konkan Railway a reality, for implementing the ACDs too.

Economics of the ACD project, with BOT option is given in Table 10.5. In terms of NPV the BOT option saves Rs 600 cr to the railway,as shown in Table 10.5.

Table 10.5 Economics of ACD Project

Year	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12
KRC spends	500	600	500						
MoR pays KRC	200	200	200	200	200	200	200	200	380
Debt raised by KRC	300	400	300	-200		200		200	-380
Interest@7%	21	50	75	66	57	47	36	25	0
Cum debt	321	771	1146	1013	870	716	553	377	-3
NPV of BOT option 1228 NPV of Direct funding from MoF 1899	**1228** **1899**								

Payment of 12 years with dividend liability at 7%

Once the system is in position, the ACD network will also help in continuous tracking of trains, providing the centralized on line information. Further the data of statistical information of their working will lay the foundation for the concept that multiple path concurrent decision systems based on low cost commercially available electronic equipment reinforced with the knowledge
base, lead to functionalities associated with more expensive signal equipment .That means non-signal standard s of equipment will deliver functionality of signal equipment! This leads to cost cutting and better and safer operations.

10.5.2 The Self-Stabilising Track (SST) Project

The concept fundamentally uses the train energy to stabilize itself and so leads to many advantages. Directly it saves ballast amounting to 2 cum per meter, which itself contributes recurring saving in the annual recoupment. To implement over 25000 track km covering 10000 route km of intensively used golden quadrilaterals, a BOT scheme is proposed. This is one case the railway will be paying only from the savings and realizes benefits even from the third year. Annually at current prices Rs 900 cr will be saved from the revenue expenditure, with significant positive impact on the operating ratio.

- **The typical costs for installing SST and savings are as under for 5000 km.**

25000 track km on core routes will be covered

The cost of providing the SST at Rs 30 lacsper km over 5000km per annum

Annually 5000 km means saving Ballast recoupment at 10% per annum At Rs 1000 per cum of ballst in track for 5000 km 5000x10%x2.5cumx1000	:	Rs cr 125 annually
Value of released ballast from existing track at Rs 500 per cum at the rate of 1.6 cum per meter for 5000km	:	in the year SST is 400 installed
Maintenance cost at 2% for the SST @ 2% of Rs 30 lacs perkm	:	30
Maint costs with machines at Rs 20000 per km for 5000 km	:	10

- **Financial snapshot for the Konkan Railway-25000 km SST on BOT**

Year	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12
KRC spends Fig in Rs cr	1500	1500	1500	1500	1500				
MoR pays KRC	945	945	945	945	945	945	945	945	933
Debt raised by KRC	555	594	635	680	727	-722	-772	-826	-872
Interest@7%	39	80	125	172	223	173	119	61	0
Cum debt	555	1149	1784	2464	3192	2470	1698	872	0

- **For Indian Railways BOT option saves Railway Rs 6000 Cr!**

Year	03-04	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12
Cashflows for Railways Rs Crores									
Outflow	945	945	945	945	945	945	945	945	933
Maint	30	60	90	120	150	150	150	150	150
Saving in recoupment	0	125	250	375	500	625	625	750	750
Value of released ballast	400	400	400	400	400				
Saving in O&M costs machine	10	20	30	40	50	50	50	50	50
Net cash-outflow for Railway	**-565**	**-460**	**-355**	**-250**	**-145**	**-420**	**-420**	**-295**	**-283**
NPV of BOT option	-2132								
NPV with MoF funds	-8284	Over 14 years							

- **Over next 8 years one can see that the preset method of maintenance practice will cost in NPV terms Rs 6076 cr, while if we adopt the SST. we spend only Rs. 864 cr!**

Current model									
Recoupment	1000	1000	1000	1000	1000	1000	1000	1000	1000
Machine maint	55	55	55	55	55	55	55	55	55
Total O&M	1055	1055	1055	1055	1055	1055	1055	1055	1055
NPV of costa over per	6076								
With SST									
Maintenance costs	150	150	150	150	150	150	150	150	150
NPV of costs	864								
Annual saving over 25000 km			**Rs Cr**	**905**					

10.5.3 Financial Aspects of Technologies

Adopting Konkan Railway Technologies, future development of Indian Railways may derive following tangible results.

- Even during the BOT phase, the railway even though will be paying Rs 945 cr per annum over next 8 years to the KRCL, in reality only Rs 400 to 500cr is the true cash-outflow to Railways! But KRCL would have spent in the first 5 years at Rs 1500 cr per annum over 5 years and installed the SST on the 25000 km!

- This is a truly a win-win scheme! With annual savings of Rs 900 cr the operating ratio will certainly look a little more better! Additionally track becomes safer and riding quality improves with cascading savings in costs of rolling stock maintenance.

- With Sky Bus technology, having potential to earn royalty of Rs 7000 cr to Railways through Konkan Railway, if only we have courage to invest Rs 50 cr the financial status of Railways in India can be redefined to become totally self-sufficient, adding wealth to the nation, in the following areas:

- Urban Transport: A business opportunity of Rs 70000 cr with potential to earn management fees of Rs 7000 cr in addition to royalty of Rs 7000 cr! If Railways execute on BOT basis, recurring profits after taxes, amount to another Rs 3000 cr per annum, considering only Indian projects! Why should we deny ourselves this opportunity, and choose to remain poor?

- Inter-city High Speed (200 kmph) Sky Jet service: The Sky Bus technology provides for carriage of both goods in containers and people to move at 200 kmph between cities. Rs 4000 cr per annum is annual profit indicated even for one single route of Mumbai-Delhi. We score in terms of quality of servicedelivering within 7 hrs cargo and people too! That too at fare of Rs 2500 per container.

10.6 Conclusion

The gain to the nation is many folds more and estimated conservatively as follows :

- The operating ratio of Indian railways can be improved to 85% from current 95%, assuming we do not reduce any employment: that means an annual saving of Rs 2500 cr! (Rs 1000 cr from infrastructure O&M ,additional revenues from royalties Rs 1000 cr/annum, productivity factors tech driven Rs 500 cr plus Rs 5000 cr from exploiting Sky Jet and Bus)

- On a continuing basis the capital investments required to augment the capacity in railways will be reduced by many orders, and the financially viable railways will be self-sustaining.

- Collisions and accidents like derailments involving human lives and assets will be eliminated significantly contributing to loss-prevention.

- The capital and operating costs at ports will be dramatically improved to gain competitive edge on global basis.

- Inter-city rail travel at 200 kmph will boost the country's productivity by eliminating unproductive idle journey times during working hours. And cargo too is handled more efficiently at the same speeds!

- Urban transport using Sky Bus will catapult our cities to be the least polluted and comfortable cities comparable to the best in the world, as well as stop the need to invest any more funds in economically white elephant road based improvement schemes or unviable expensive mill-stone metro rail systems.

We need self-confidence and nothing else! We do need a committed technosavvy quick decision making structure to realize these benefits.

We must unlock value of our assets both human and infrastructure, by reorienting ourselves and take the policy initiatives.

A passionate commitment is needed to place our Indian Railways in the forefront, leading in the world with cutting edge technologies, which is well within our reach, given the core knowledge base our country is built on..

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Patents:

All The Patents are in name of B RAJARAM as INVENTOR and stand assigned to PRESIDENT OF INDIA.

- Sky bus Metro -A Novel Suspended Coach Transportation System

  Five Patent Applications

  6. Sky Bus Metro- No 715/MUM/01
  7. Swing Arrester- No 716/MUM/01
  8. Derailment Arrester- No 717/MUM/01
  9. Collision Arrester- No 718/MUM/01
  10. Suspender- No 719/MUM/01

- Anti Collision Device –
  Patent Application No 668/BOM/99 dated 24.9.1999