IIM – IDEA Telecom Centre of Excellence

Project Course

Intelligent Rail Transport Systems

A report submitted to

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Introduction

Intelligent Transportation Systems

Transport Canada defines Intelligent Transportation Systems (ITS) as “a broad range of diverse technologies applied to transportation to make systems safer, more efficient, more reliable and more environmentally friendly, without necessarily having to physically alter existing infrastructure.” The technologies employed could be such as communications, computer informatics, sensor and control technologies and spread across domains such as telecommunications, finance, e-commerce and transportation. The application of such technologies for increasing the efficiency of railway services is known as Intelligent Rail Transport Systems.

The rail network is an important transport infrastructure enabling transfer of people and goods across places all over the world. There is tremendous scope for improvement in the freight and passenger carriage by appropriate use of modern technology to improve its services. There is a predictable high demand for ‘high density- high speed’ rail network in the 21st century and Intelligent Rail Systems is one of most possible way to achieve it. This would put the rail as the preferred mode of transport for both people and goods thereby increasing the asset utilization of the railways and decreasing the demand for fuel and road infrastructure. The recent advances in technologies in telecommunication and computing have made it possible to develop an intelligent rail system.

Objectives

Indian Railways (IR) is the second largest rail network in the world under a single management. The scheduling of passenger and freight trains, the tracks and enforcing safety standards in IR presents a huge challenge. About 14 million passengers and more than a million tonne of freight traffic are transported everyday. Given the importance of IR in the economy of the country, it is imperative to utilize its assets to the maximum extent possible. This increase in efficiency would mean more freight being carried through rail, more passengers being carried in lesser time and without compromising on the safety aspect. The use of efficient communication channels would enable the IR to increase their efficiency tremendously.
1. In this paper we would explore the telecom and allied technologies that can be employed to improve the passenger and freight rail services. Such technologies include Geographical Information Systems (GIS), Global Positioning Systems (GPS), GPRS, RFID, etc. Some of the IT systems that would be considered necessary for the implementation of such systems would also be explored although in brief.

2. The study of the current status of the Indian Railways (IR) and the necessary steps and issues concerned in implementing the ITS systems and its consequences in IR would also be explored. The study would comprise the technologies and changes needed that aim to increase to the efficiency, quality of services and safety:

   I. Higher Efficiency
      - Intelligent Freight Operation Systems
      - Intelligent Fleet Management Systems
   
   II. Higher Quality of services
      - Intelligent E-Business System
         - Mobile Ticketing
      - Intelligent User Information System
   
   III. Higher Safety
      - Intelligent Safety and Supervision System

3. Arrive at recommendations based on the above study.

**Methodology**

The methodology followed for this study is a combination of primary and secondary research. Primary research was done to evaluate the current efforts by the IR in implementing the ITS, difficulties involved in implementing these technologies, feasibility, future plans, etc. Secondary research was conducted to identify and study similar projects elsewhere, their successes as well as the difficulties encountered during their implementation. The information gathered was evaluated for its feasibility and relevance in Indian context. Also ITS projects in other industries (e.g. airline ticketing, concert tickets, freight tracking in roadways, etc) were studied to evaluate the possibility of adopting similar models in rail.
Project Scope
The project as a whole would deal with role of telecom techniques in increasing the efficiency, safety and quality of services of Indian Railways. This entails exploring the information relating to the current status and progress worldwide in this regard. In addition it would also require data specific to the region such as mobile penetration, prevalent mobile standards, etc to arrive at any specific conclusions for the region.

Background Study
The Basic Buildup of IRS
Intelligent Rail System (IRS) is new generation transportation system brought about by the integration of telecommunication, electronic, navigation, control, decision support and automatic technologies. These technologies would enable the optimum use of all the available fixed and mobile resources, time, space and human resources in railways with the objective of improving the efficiency of transportation, increased safety and service quality at minimal cost. The technologies involved are GIS, GPS, GSM (including GPRS) and other computing technologies. The technologies used would ultimately aim to result in either of the following: increase in efficiency, safety or quality of services.
I. Intelligent Railway Operation Management System

Indian Railways’ current status on freight and fleet
(http://www.irfca.org/faq/faq-freight.html)

IR carries a whole spectrum of goods ranging from parcel traffic, small consignments, coal, agricultural products such as fruits, raw materials like iron ore and steel, and finished goods like automobiles. Over the past few decades, IR has showed a tendency to move away from small consignments or piecemeal freight, and instead has focused more on increasing number of block rakes, in which case the shipper contracts the entire rake assigned to carry the load. This business model seems to be benefiting the IR as they have tried to cut down time on marshalling & transit time, and scheduling as the rake doesn’t require to be split up or joined. This explains the reason for coal and other bulk commodities such as iron ore, steel and cement forming about 70% of the
weight carried by IR. (Exhibit 1 and 2). A full rake consists of 40 BCN wagons and half-rake 20 wagons.

According to the *India Infrastructure Report 2008: Business Models of the Future* (3iNetwork, Oxford University Press), the railways have been registering higher growth in lower rated coal and food grains while recording insignificant growths compared to the production in the high rated sectors such as steel and cement. The petroleum sector under government control is also proactively involved in laying pipelines for the transport of petroleum.

The Indian Railways owns a fleet of 216717 wagons, 39236 coaches and 7739 number of locomotives. It operates 14444 trains daily, inclusive of about 8,702 passenger trains. They carry about 14 million passengers and more than a million tonnes of freight traffic daily. (http://www.indianrail.gov.in/abir.html)

The process of intelligent fleet and freight management, using the various location-based technologies and integrated dispatching would increase the asset utilization for the railways.

**Freight Transportation**

The Railways have the following disadvantages vis-à-vis the roadways

1. Higher priority accorded to passenger transport
2. Rail services not able to include the production concepts (such as JIT, different payloads) of the customer

Two main causes being attributed for the loss of freight market to the roadways are:

1. Relatively higher freight rates to subsidize the passenger fares
2. Low average speed of freight trains due to higher priority being accorded to the passenger trains

As the table shows (Exhibit 3), the share of railways in freight transport has dropped from 78.45% in 1950-51 to 25.76 % in 2000-01. But IR is still very well established in the mine-to-industry segment i.e. transport of coal, iron ore, etc. But it loses out to roadways in the collection/industry centres to distribution centres segment such as cement where there is intense
competition. It becomes imperative for Indian Railways to provide service on par with other private roadways players to regain the lost market share.

Railways introduced a number of initiatives aimed at reversing the trend of losing the freight market share such as freight rate structure rationalization, empty flow discount, commodity grouping simplification, volume discount and a variety of such offers. With the exports and imports slated to rise in the future, the traffic flow to and from the ports offers enormous potential to the IR, which currently holds 30% of the market. The requirements for transport of coal and container traffic would go up considerably. (http://www.thehindubusinessline.com/2008/07/12/stories/2008071250150800.htm).

The Dedicated Freight Corridor which allows goods trains to travel at a faster pace than what it is currently and allows double stacking of containers is essential to tap the container freight market.

**The Demand for Freight Rail Transportation**

The demand for freight services depends on the overall economic activity, relative proportions of economic activities such as services (doesn’t require transport) and manufacturing, and the location of economic activity (for the transport of raw materials to the location of manufacturing, and finished goods to the place of consumption)

**Freight Operation Information Systems (FOIS)**

One such initiative by the IR to increase the customer service was to provide them with real time tracking of goods. The FOIS provides the customers with the location of their rakes at any point in time. The digital communication facilities owned by IR along with some hired BSNL channels provide the necessary telecom infrastructure. The project when conceived was to provide the location of individual wagons but as of now is able to provide the position of rakes only. (http://www.it.indianrail.gov.in/fois/foisbrief.htm).

The other main objectives of the project included extension of the “hub and spoke” model to piecemeal traffic, and to facilitate acceptance of customer's orders, billing and cash accountal
from predetermined nodal customer centres which would eventually be extended to customer’s doorstep in the form of e-commerce.

Though they provide real time tracking of goods, the operations are not entirely automatic\(^1\). Out of the 68 divisions existent, about 45-50 have been computerized (\text{http://indianrailway.fotopic.net/}). Each of these divisions has about 100 stations, the station being the unit of operation. It is only at these computerized stations, the data about the position of the train is manually fed into the system after having the visual contact of the train. By the customers of IR, few actually demand real time tracking of goods as most of the goods carried by IR belongs to the bulk category where time lag is not considered significant. But of late, customers belonging to the cement industry have started demanding real time tracking of their goods. Other than this segment, the container segment customers demand real-time positioning of their goods.

The two technologies that can actually be employed by IR to provide for real time positioning of customers goods are the GPS based system and RFID based system. Currently, Konkan Railway employs Data loggers and Mumbai suburban trains use Axle counters to determine the position of the trains.

Currently the IR is offering the online freight tracking facility to its customers. The customers are given login user ID through which they can track the position of the rake which is carrying their goods.

The operations of FOIS can be divided into two modules; Rake Management System (RMS) and Terminal Management System (TMS). RMS is concerned with maintaining the inventory of rolling stocks and the movement of rolling stocks. The TMS is concerned with the commercial info of freight i.e. charges, collection, station level activities, etc.

The system deployed is a three-tier system which was jointly designed by CRIS and CMC. The backend or database is RDBMS/oracle, application server is Tuxedo (of BEA) and the frontend comprises of web logic or visual basic. All loading stations or traffic people are provided with terminals. The demand which is generated is fed into the RMS, a rake is sent to the commercial entity and the rake is linked to the demand.

\(^1\) Personal communication with Mrs. Saroj Ayush, Chief Manager, Container Corporation of India Limited, Ahmedabad
The opportunity cost of rakes is extremely high and added to it is the cost of running an empty rake which prompted the IR to search for a mechanism to keep a track of its rakes. Sometimes empty rakes travel long distances before the officials track them down or lie empty without being utilized even in times of high demand.

**GPS based positioning systems**

GPS based positioning systems consists of on-board GPS equipment, GPS satellite and GPS receivers to capture the signals transmitted by the satellites. The entire architecture is described in exhibits 4, 5 and 6.

GPS systems would work well in areas where there is no obstruction to signals where as in areas where there is chance of obstruction to communication between the satellite and the equipment or receiver as in dense vegetation areas, in hilly terrains or in tunnel, the monitoring system has to be supplemented by another reliable system such as axle counter which adds to the complication of integrating two different systems to provide tracking services to the customers. GPS services are provided for free by the US and anyone with a receiver can receive the GPS signals. ISRO is involved in deploying the GPS tracking system for IR on a pilot basis. The pilot projects of IR on GPS are being undertaken at various places. The main objective of using this technology is to increase the asset utilization of the tracks. By installing GPS on each locomotive it becomes possible to track them with an accuracy of few metres. By using such systems it becomes possible to direct the trains to such tracks where another train is ahead by atleast one block. Without these it was difficult to run the trains on the track until some manual signal was passed on from the next station to the traffic control regarding the position of the train. The system makes it possible to accord precedence to trains. One offshoot of this system is that the position of the trains can be passed on to the passengers, which is a kind of value added service by IR. Although currently it is possible for IR to pass on information about the position of the trains to customers by displaying at the stations, this information is nothing but the same manual information which is provided at subsequent blocks and not continuous information as seen in GPS systems. IR doesn’t have any plans to tie up with cell phone service providers to

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2 Personal communication with Mr. Raghavendra Kumar Sharma, Chief manager/ Systems, CRIS
pass on the information to the passengers. According to Mr. Raman Bansal, the system of providing information about the position of trains already exists. What GPS has to offer is much more accurate information about the position of the train. The position of the trains can be uploaded on the website and the cellular service providers can collect information about it from the website and then pass on the information to their customers. Since the technology is still under proposal for a nationwide rollout, the commercial aspects of it haven’t been explored yet. ISRO is the main vendor for GPS. It takes approximately Rs 30000 for fixing one GPS unit to a locomotive. Recently, the Western Railways had partnered with netCORE portal called ‘mytoday.com’ to deliver updates on trains( http://www.expressindia.com/latest-news/now-railway-updates-on-your-mobile-phones/349201/). To kickstart this service the commuter has to register by sending out a SMS. Once registered the updates will be delivered depending on the station for which the request is sought. This service is free and is charged only the nominal fee of a SMS. Subscribers of any cellular service can avail this facility. With such a system already coming into existence it wouldn’t be difficult for the IR to feed the information on position the trains into this system.

**RFID based positioning systems**

A RFID based positioning consists of a RFID tag and a reader to read the transmitted signals. A RFID tag consisting of an integrated circuit chip and antenna enclosed in a shell can be attached to objects or be embedded in them. It can be used to track consignments as the rail moves through various stations through a reader installed at every station. Using this technology, the customer can be confident that the right consignments have been unloaded at the right destinations as well as keep track of position of his consignments during the course of the transport. This technology is yet to become widely accepted due to accuracy and interoperability factors.

The product information is stored as electronic product code (EPC) in the RFID tags. The EPC from various tags is read by readers and is then communicated to middleware software (Savant) which in turn matches the information with the information in several databases (object naming services (ONS) and product markup service (PMS) servers). Then, the detailed product information gets relayed to local information system databases. This information is in turn is fed into various ERP and SCM systems to support decision making.
The architecture of RFID components and its integration to information systems is as shown in Exhibit 7.

**Challenges in RFID implementation**

The challenges in implementing RFID based systems include its cost, standards, privacy and security and Information Technology reconfiguration. According to Venables (2005), though RFID has potential for significant benefits, parallel systems have to be used until RFID is used comprehensively and integrated with existing technology, thus enhancing the cost and complexity.

There are different types of costs associated with the implementation of RFID based systems. The investment costs for procuring physical equipment such as tags, readers, printers, and other related softwares and network infrastructure (Deloitte, 2005). There are associated recurring costs on tags, labor costs, system maintenance, etc. The cost of tags is high, but decreasing. The pricing is based on volume ordered, the memory capacity of the tag and the packaging (e.g., encased or embedded).

The various components of “slap and ship” solution as described in Sirico (2005a, b) are shown in Exhibit 8. This system functions optimally for about 250000 units per year. The additional labour costs and annual maintenance costs are also to be added to the figures given in the table. This figure is approximate and would vary with the scope of the project. Exhibit 9 provides us with an idea of an estimate of initial fixed costs and annual maintenance costs.

The pilot projects of IR are underway at certain locations such as Paradeep port, ore exchange complex, etc. This pilot project is aimed at maintaining the inventory of rakes and controlling their movements on a real-time basis increasing the asset utilization of IR. The proposal includes installing RFID readers at major stations. One of the off shoot benefits from this technology was that the information about the position of wagons could be passed on to the freight customers as well. But as stated this is not their main objective. Their main objective is to increase the asset utilization of wagons by keeping track of the number of empty wagons. Since this would be done at the national level, there is scope for further increase in the asset utilization of wagons since empty wagons in zone or division can be utilized in another zone or division. Currently this is not possible since the information about the wagons is available only to the respective divisions and zones. If the program is implemented CRIS would be the central organization from where
decisions could be made without any distinction between the zones. Since the project is mainly for control purposes rather than a value added system, the IR requires information only at the wagon level which can subsequently be passed on to customers.

During the pilot phase, certain problems in RFID implantation were encountered. One of them was that the overlapping of reader areas between two readers installed for two different tracks but later was resolved. Another potential problem was the memory capacity of the chip was getting rapidly updated.

Conclusion

Freight is the main revenue earner for railways. Hence a greater focus must be ensured on the freight customers to provide services on par with the trucking services in certain segments. Though superior technology is available currently, parallel improvement in other related avenues is also essential to realize the growth envisioned while adopting newer technologies.

1. Improvement in the average speed of the goods trains is required to attract customers who are time sensitive. Customers who are time sensitive who require real-time tracking also would want their goods to be delivered on time and at faster rate. If the average speed is lesser than the trucks, then there is no use providing real time tracking for goods.
2. Dedicated freight corridor: The commissioning of dedicated freight corridor would enable double stacking of goods and allow the freight trains to travel at speeds 70-100 kmph. This would attract the container customers who in turn will require real time tracking.
3. Rationalization of freight rates: Freight rates when higher than the truck rates prevent the customers from utilizing railway services. The competitive rates along with real-time tracking facilities and door-delivery services provided by the trucking companies are compelling for the customer. The railways has to offer competitive rates to attract those customers.
4. Investments into specific commodity related wagons have to be made to meet the demand (e.g. certain type of finished steel, bulk-load of cements requires special wagons)
5. Increasing rail connectivity to ports to tap the potential container customers.

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3 Interview with Raghavendra Kumar Sharma and Manish Kumar, CRIS
The significant costs and complexities involved in integrating the applications in either RFID or GPS, without assessing the demand for such services in Railways has to be given a second thought. The reason for such implementation in other countries was the type of goods that were being carried which included highly valuable goods, parts for automotives where JIT was the driving factor, dangerous materials and chemicals, where the requirement for real time information was high in frequency as well as detailed (box level, etc) and the inter-station distances were pretty high. The railways were ready to meet the additional traffic that would come by offering such services as there was no shortage of trackside infrastructure. But in India, there is a mismatch between the units and the trackside infrastructure. The units have to wait for the infrastructure to get cleared. It is better to improvise on the other aspects and then go ahead with the implementation of costly and complex tracking technologies.

II. Intelligent User Information System & E-business system

With the advanced Information and communication technologies available today, it has become possible to provide highly sophisticated service to passengers be it road, rail or airways. Any information regarding delays, ticket prices, ticket availability, etc help increase the customer service. They help the consumer make sophisticated plans using sophisticated information. This information could be transmitted through a variety of media such as mobile phones, internet, etc.

a. M-Ticketing

One such service to passengers is the Mobile ticketing (M-Ticketing). Using this service the passenger need not stand in the queue anymore to buy their tickets either at the counter or at the ticketing machines. He could just order M-Ticket through internet, IVRS (Interactive Voice Response System) or SMS after registering his mobile number with the service provider. The service provider will then dispatch a ticket in the form of a code through a SMS to the passenger which can be verified by the ticket checker who has a GPRS enabled hand-held terminal which communicates with the central database. The payments can be made through weekly debits or
through e-wallets\textsuperscript{4}. The Helsinki Transport Corporation was one of the pioneers in introducing Mobile Ticketing in public transport.

Of the 14 million passengers that are being carried by Indian Railways everyday, about 0.5 to 0.7 million have reservations. The rest 13.5 million passengers travel on tickets. However among these passengers there may be daily travelers for whom passes would be economical. The target passengers for this service would be the not-so-frequent travelers. However the adoption of such a system in India poses significant problems. As everywhere such a service is adopted by urban passengers than rural and the return on investment is highest in urban areas. The adeptness of Indian passengers in using SMS facilities also comes into question. There are also other issues as found out in the survey conducted in Netherlands. Such issues include worry about not receiving the SMS, low battery in mobile phones, etc. (Exhibit 10 & 11).

While overwhelming number of passengers have expressed that they didn’t find any difficulty in using the mobile phone for ticketing, the technology in use must be of easy user interface. In the Indian context, given the number of languages in use and literacy standards, the use of voice portals (IVRS) for ticketing would be the most optimum. However more research on the mobile penetration of rural and urban areas, the adeptness in using the SMS facility among the travelers, etc. is needed before reaching at any conclusion. To overcome such difficulties, a voice portal which repeats the ticket code vocally in addition to sending the SMS would help the passengers. Currently Indian Railways has been conducting trials of the mobile unreserved ticketing system. The pilot has been operational for about 6 months and is expected to become fully operational by March 2009\textsuperscript{5}.

The entire chain of the operations has 4 components:

\textbf{End user} \rightarrow \textbf{Mobile service providers} \rightarrow \textbf{Mobile transaction application (3rd party)} \rightarrow \textbf{IR}

The end user places a request from a mobile device in the form of text message through embedded application or WAP. Currently IVRS is not being considered. This request is routed through the mobile service providers. The mobile transaction application will be outsourced to

\textsuperscript{4} E-wallets – also known as digital wallets – allow users to make digital payment transactions quickly and securely. An e-wallet essentially functions just like a physical wallet, in that it is used as a means of storing various forms of electronic money (e-cash) which can then be used to pay for goods or services. The mechanism for payment varies, but usually relies on either a card being swiped through a reader, or some form of contact-less payment using wireless technology such as Near Field Communication (NFC) technology.

\textsuperscript{5} Personal communication with Mrs. Monica Malhotra, Chief Systems Manager/ Unreserved Ticketing System, CRIS.
some third parties. The parties would have paid the IR an advanced deposit and as the tickets are booked, amounts are deducted from this advance. After the transaction, the request finally reaches IR. The third parties which have expressed interest in hosting the mobile transaction application are Airtel, M-check and Oxigen. IR does not intend to get into the retail monetization.

There are three different types of messages that the IR is considering for the implementation. They are pictorial messages, bar codes and textual. Each type of messages has its own limitations. The pictorial messages are severely limited by being available to use only in MMS supporting phones. The limitation with bar codes is that the passenger cannot read and verify the information that has been sent. The problem with textual messages is that it is difficult to make it non-editable. Hence IR has not still zeroed on in the type of message to be used on a permanent basis.

**Problems encountered during implementation**

The solution provided is not a truly mobile solution in that it is mandatory for the passenger to utilize another facility such as a reader. The system has not been able to devise a mechanism to prevent passengers from purchasing tickets once they have boarded the train and traveled a certain distance. Hence the only way to prevent this is to print the ticket at preinstalled mobile kiosks before the passenger boards the train. This would again entail that the passenger stands in queue to print his ticket which was not to be the case as per the objective of the project. Hence to prevent queues a large number of kiosks have to be installed for the passengers to get their tickets printed.

Other than this the commercial model is still under deliberation. Efforts are being made to arrive at a commercially viable model.

**b. Passenger reservation system**

The total daily reservations handled by the PRS are of the order of about 1 million. This reservation system has been in place since two decades and has done extremely well. But of late with increasing numbers and complexity (Exhibit 12) there has been growing concern about the scalability of the system.
Most of the people use the reservation counters at the railway stations to reserve their tickets. The number of passengers ordering tickets through internet/credit card system has been miniscule. One of the common causes for this is the general aversion among the Indians towards the concept of credit. To counter this, Indian Railways came up with debit card deductions. Whether the mechanism of mobile booking along with e-wallet would be a feasible solution for PRS remains to be seen. IRCTC has introduced a system where the users of GPRS and Java-enabled phones can book their tickets using their mobile phone. But this works through the availability of internet in these phones. A method similar to unreserved ticketing system where passengers with low-end handset can reserve their tickets is complex as it involves multiple menu items.

Another flaw recognized in the Railways booking has been their policy towards charging higher fees for tickets that are booked through internet. This policy instead doesn’t help in reducing crowding at the reservation counters at stations. (www.expresscomputer.com)

The adoption of such payments through mobile phones depends on the way the passengers perceive the transactions to be. Hence it is important to reassure the passengers that the payments made through mobile are safe and secure. The payment mode should also be easy to use and intuitive. Another issue that crept up during a concert in US for which tickets were sold through mobile was the purchase of tickets in bulk and subsequent sale of it through black market. To counter this checks have to be put by introducing tabs on the number of tickets that a person can purchase from a mobile number. But this does not prevent the culprits from having multiple mobile connections and ordering in smaller quantities to avoid detection.

III. Intelligent Safety and Supervision system

A look at the Train accident statistics in India (Exhibit 13 & 14) will reveal the status of IR on safety component. Though other type of accidents such as derailments and collisions has been decreasing, the level crossing accidents have remained constant over the years or have increased recently over the 1996-97 levels.

The navigation technologies coupled with signaling equipments can reduce the number of these incidents by increasing the safety. In the absence of trackside equipment, increasing transport load leads to an increase in the errors. Equipping these lines with signaling systems is highly
uneconomical. Supplementing navigation receivers with other equipments such as odometers, balise and gyroscopes along with other communication services between the driver and the central station will increase the safety levels.

**Track survey**

Surveying the tracks is an important task, for which accurate positioning and synchronization between the components of system is essential. The traditional techniques such as track circuits are not sufficiently accurate and hence geodetic survey is needed. The real time GPS monitoring can be used to monitor the integrity of the system.

**Causes of Train Accidents:**

A high number of accidents 169 (87.11% of the total) was attributed to the human error out of the 194 train accidents that occurred on IR during 2006-07. A further breakdown shows 85 (43.81%) accidents due to the failure of railway staff and 84 (43.30%) due to the failure of non-Railway staff. A low number of deaths 9 (4.64%) were caused by equipment failure.

(http://www.indianrailways.gov.in/deppts/stat-eco/yearbook-0607/safety.pdf). A slew of measures have been introduced to reduce the accidents. Axle counters have been progressively deployed which is a reliable indicator to judge if a train has passed a particular location. The use of GPS enabled safety systems has to be again augmented by other safety systems such as the axle counters as GPS has severe limitations in locating the trains in hilly terrains, in areas of thick vegetation and within tunnels. The safety systems as a whole cannot rely on the GPS. The requirement of two different systems complicates the backend processes involved. Currently, IR does not use GPS for safety purposes as they were found to have certain limitations in reporting the movement of trains with an accuracy of few inches\(^6\).

**Guidelines by Institutions for developing countries for implementing ITS**

Developing countries often are at a disadvantage when it comes to constructing their infrastructure. But this also saves them from the cost of experimentation in that they can adapt the tested models from developed countries. A similar argument is being put forth for developing countries that are in the process of rolling out Intelligent Transport Systems in their respective countries.

The arguments are:

\(^6\) Personal communication with Raman Bansal, CRIS

*Intelligent Rail Transport Systems*
1. It is easier to lay the IT/electronic infrastructure along when the physical structure is being constructed
2. The cost and complexity of laying a new IT infrastructure is lesser than upgrading an old infrastructure
3. The developing countries have the added advantage of adapting the best methods deployed by different nations
4. The current mobile technologies and Internet can be used to integrate the system in an advanced manner.

Prerequisites
Before embarking on ambitious projects, the decision makers have to understand the prerequisites for the deployment of systems of such magnitude. The knowledge of both the traditional and ITS-enabled transport systems is vital to the planners and developers to understand the interaction between them and develop them in tandem and systematically. It is important to realize that ITS comprises of all modes of transport and optimization occurs only when all modes are intelligent. Hence it is pertinent to implement ITS on all modes in parallel as far as possible. There is a possibility that the standards implemented in one mode will become obsolete when other mode is being worked on. Traditional standards have to be broadened to include the standards and protocols for communication systems and IT devices that are part of ITS.

Two prerequisites that have been identified as necessary for implementing ITS in developing nations are: Institutional and Technological

Institutional Prerequisites
- An independent organization which champions the cause for the deployment of the ITS technology and also which acts as an catalyst for fostering public private partnerships between the governments and private players in developing such infrastructure and also actively participates in development of standards.
- The existing laws and regulations have to be modified to incorporate ITS systems and architecture or in some cases new laws and regulations have to be created
- A channel must be provided to include the viewpoints of different consumers and end users which has to be incorporated in development of the systems
• The institution must also provide for the training of human resources that develop and administer ITS

**Technological Prerequisites**

• A common data model to coordinate and simplify the various information different sources

• Establishment of communication standards such as message sets, data dictionaries and protocols aimed at promoting interoperability and flexible enough to accommodate to the rapid technological advances

• Since recent ITS technologies use wired or wireless communications and being built on the existing infrastructure, adequate bandwidth and coverage has to be ensured by the planners

• An international standard that suits the local conditions must be adopted. An expert panel which participates in the draft development of international standards would help this cause.

**Need for regulatory standards**

Regulatory standards in ITS is aimed to promote uniformity and interoperability so that the systems across work in tandem without any technical glitch and paves the way for future upgradation at lower costs. One such example is the Smart card that can be used all over the nation in all modes of transport. If different agencies use different cards and in future if integration of the agencies is possible, then the smart cards have to be reissued. Hence it becomes pertinent to study the nations that have implemented ITS systems before adopting any standards.
### Exhibit 1

Freight carried by Indian Railways in 2006-07

<table>
<thead>
<tr>
<th>Commodities</th>
<th>Million Tonnes</th>
<th>% (by weight)</th>
<th>% (by revenue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>313.33</td>
<td>43.05</td>
<td>38.68</td>
</tr>
<tr>
<td>Foodgrains</td>
<td>41.84</td>
<td>5.75</td>
<td>7.48</td>
</tr>
<tr>
<td>Iron &amp; steel</td>
<td>27.04</td>
<td>3.72</td>
<td>6.33</td>
</tr>
<tr>
<td>Iron ore &amp; other ores</td>
<td>121.74</td>
<td>16.73</td>
<td>13.8</td>
</tr>
<tr>
<td>Cement</td>
<td>73.13</td>
<td>10.05</td>
<td>8.88</td>
</tr>
<tr>
<td>POL (Mineral oils)</td>
<td>31.69</td>
<td>4.35</td>
<td>6.96</td>
</tr>
<tr>
<td>Fertilizers (Chemical manures)</td>
<td>34.26</td>
<td>4.71</td>
<td>4.36</td>
</tr>
<tr>
<td>Limestone &amp; dolomite</td>
<td>12.7</td>
<td>1.75</td>
<td>1.76</td>
</tr>
<tr>
<td>Stones (incl. gypsum) other than marble</td>
<td>13.22</td>
<td>1.82</td>
<td>1.44</td>
</tr>
<tr>
<td>Salt</td>
<td>4.63</td>
<td>0.64</td>
<td>0.93</td>
</tr>
<tr>
<td>Sugar</td>
<td>3.68</td>
<td>0.51</td>
<td>0.66</td>
</tr>
<tr>
<td>Total</td>
<td>677.26</td>
<td>93.06</td>
<td>91.28</td>
</tr>
<tr>
<td>Commodities other than above</td>
<td>50.49</td>
<td>6.94</td>
<td>8.72</td>
</tr>
<tr>
<td>Grand Total</td>
<td>727.75</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>


Note: Other commodities include ISO and domestic container handled by Concor (5.17% by revenue), gypsum, fodder oil cake, non-ferrous metals, fruits and vegetables, marbles, bamboos, edible oil, oil seeds, jute manufactured, soda ash, paper, etc.
Exhibit 2: Freight Carried by Indian railways (% by weight)

![Pie chart showing freight carried by Indian railways (% by weight)]

Compiled from the data extracted from: Freight Operations Annual Report 2006-07. Indian Railways

Exhibit 3: Rail and road traffic volumes and modal shares

![Table showing rail and road traffic volumes and modal shares]  


Modal Split between Rail and Road Modes of Transport in India
Exhibit 4: Control Centre Design

Exhibit 5: On-Board unit Design

On-board unit design: The on-board unit use GPS to determine its geographical position. The signals emitted by satellite in the GPS are analysed at the time intervals defined in advance or simply on request (Chakrabarti, et al., 1999). This enables the position of the mobile unit to be calculated. GPS signal cannot continuously provide the positioning information when GPS signal obstruction occurs in the tunnel or under the trees, so auxiliary devices and techniques are needed to provide supplemental positioning information for vehicles in above cases. GPS, transponder and odometers will be used to position the on-line train in the Qinghai-Tibet railway. GPS receivers will be fabricated on a circuit board, and transform the data to the desktop computer, thus realize real-time positioning and display.
**Exhibit 6:** Communication link architecture

Extracted from: Bin Wang, Qingchao Wei, Qulin Tan, Shonglin Yang, Baigen Cai. Integration of GIS, GPS and GSM for the Qinghai-Tibet Railway Information Management Planning

**Exhibit 7:** RFID system components and integration to the Information Systems (based on Laran, 2005)

### Exhibit 8: Slap and Ship solution as described by Sirico (2005)

<table>
<thead>
<tr>
<th>Description</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Thermal Printer/ Encoder</td>
<td>$5000</td>
</tr>
<tr>
<td>Two dock Door Read Points, includes:</td>
<td>$15000</td>
</tr>
<tr>
<td>• 3 X EPC compliant, multi-protocol reader</td>
<td></td>
</tr>
<tr>
<td>• 8 X Bi-static 915MHz Antennas</td>
<td></td>
</tr>
<tr>
<td>• 4 X Industrial Strength Enclosure for Dock doors</td>
<td></td>
</tr>
<tr>
<td>• Cables, UPS, Lights, Mounting Hardware, ballards</td>
<td></td>
</tr>
<tr>
<td>Hardware total</td>
<td>$20000</td>
</tr>
<tr>
<td>RFID Middleware (varies by vendor)</td>
<td>$30000</td>
</tr>
<tr>
<td>External Services</td>
<td>$50000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$100000</strong></td>
</tr>
</tbody>
</table>


### Exhibit 9: Initial fixed and annual maintenance costs as described by Sirico (2005a)

*Initial and annual fixed costs of an RFID implementation (based on Sirico, 2005a)*

Exhibit 10  Disadvantages experienced during M-Ticketing

<table>
<thead>
<tr>
<th>Mentioned disadvantages of the M-Ticket service</th>
<th>Number of times mentioned (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I do not experience any disadvantages</td>
<td>28</td>
</tr>
<tr>
<td>An M-Ticket cannot be canceled or edited on the day of traveling</td>
<td>13</td>
</tr>
<tr>
<td>The M-Ticket service is restricted to only the north of the Netherlands</td>
<td>11</td>
</tr>
<tr>
<td>Uncertainty whether the SMS will arrive in time</td>
<td>9</td>
</tr>
<tr>
<td>I cannot order a weekend return ticket or a batch of return tickets for a certain route</td>
<td>9</td>
</tr>
<tr>
<td>I do not have a receipt for declaring my trip</td>
<td>9</td>
</tr>
<tr>
<td>Checking the ticket takes more time, is more laborious</td>
<td>9</td>
</tr>
<tr>
<td>The M-Ticket service does not always work/the Internet site does not always work</td>
<td>7</td>
</tr>
<tr>
<td>I do not have a ticket if I forget my cell-phone or if the battery is empty</td>
<td>7</td>
</tr>
</tbody>
</table>

Extracted and modified from: Jasper Dekkers and Piet Rietveld. 2007. Electronic Ticketing in Public Transport: A Field Study in a Rural Area

Exhibit 11: Survey regarding the ease of usage of mobile for ticketing compared to the traditional tickets

<table>
<thead>
<tr>
<th>How easy is to buy a ticket?</th>
<th>Buying a bus ticket the regular way (%) (cum.)</th>
<th>Buying a train ticket the regular way (%) (cum.)</th>
<th>Using the M-ticket website (%) (cum.)</th>
<th>Using the M-ticket voice-portal (%) (cum.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Easy</td>
<td>7 (7)</td>
<td>6 (6)</td>
<td>47 (47)</td>
<td>41 (41)</td>
</tr>
<tr>
<td>Easy</td>
<td>56 (63)</td>
<td>69 (75)</td>
<td>53 (100)</td>
<td>56 (97)</td>
</tr>
<tr>
<td>Difficult</td>
<td>28 (91)</td>
<td>24 (99)</td>
<td>0 (100)</td>
<td>3 (100)</td>
</tr>
<tr>
<td>Very difficult</td>
<td>9 (100)</td>
<td>2 (100)</td>
<td>0 (100)</td>
<td>0 (100)</td>
</tr>
</tbody>
</table>

Extracted and modified from: Jasper Dekkers and Piet Rietveld. 2007. Electronic Ticketing in Public Transport: A Field Study in a Rural Area

Intelligent Rail Transport Systems
### Exhibit 12: Complexity of PRS

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume</strong></td>
<td>Total number of transactions</td>
<td>Over 1 million per day</td>
</tr>
<tr>
<td></td>
<td>Number of passengers handled</td>
<td>Over 0.7 million per day</td>
</tr>
<tr>
<td></td>
<td>Number of reserved trains</td>
<td>Over 2800</td>
</tr>
<tr>
<td></td>
<td>Number of locations</td>
<td>1320</td>
</tr>
<tr>
<td><strong>Complexity</strong></td>
<td>Types of trains</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Types of quotas</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Types of classes</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Types of concessions</td>
<td>199</td>
</tr>
<tr>
<td></td>
<td>Types of coaches</td>
<td>123</td>
</tr>
</tbody>
</table>

Extracted and modified from: SC Srivastava, SS Mathur, Thompson SH Teo. 2007. Modernization of passenger reservation system: Indian Railways’ dilemma

### Exhibit 13: Train Accidents in India (1996-2007)

<table>
<thead>
<tr>
<th>Year</th>
<th>Collisions</th>
<th>Derailments</th>
<th>Level Crossing</th>
<th>Fire in Trains</th>
<th>Misc. Accidents</th>
<th>Movement of Traffic, i.e., Train Kms. Run (in Millions)</th>
<th>Incidence of Train Accidents per Million Train Kms.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996-97</td>
<td>26</td>
<td>286</td>
<td>65</td>
<td>4</td>
<td>-</td>
<td>381</td>
<td>667.1</td>
</tr>
<tr>
<td>1997-98</td>
<td>35</td>
<td>289</td>
<td>66</td>
<td>6</td>
<td>-</td>
<td>396</td>
<td>675.8</td>
</tr>
<tr>
<td>1998-99</td>
<td>24</td>
<td>300</td>
<td>67</td>
<td>6</td>
<td>-</td>
<td>397</td>
<td>686.9</td>
</tr>
<tr>
<td>1999-00</td>
<td>20</td>
<td>329</td>
<td>93</td>
<td>21</td>
<td>-</td>
<td>463</td>
<td>717.7</td>
</tr>
<tr>
<td>2000-01</td>
<td>20</td>
<td>350</td>
<td>84</td>
<td>17</td>
<td>2</td>
<td>473</td>
<td>723.8</td>
</tr>
<tr>
<td>2001-02</td>
<td>30</td>
<td>280</td>
<td>88</td>
<td>9</td>
<td>8</td>
<td>415</td>
<td>756.4</td>
</tr>
<tr>
<td>2002-03</td>
<td>16</td>
<td>218</td>
<td>96</td>
<td>14</td>
<td>7</td>
<td>349#</td>
<td>786.2</td>
</tr>
<tr>
<td>2003-04</td>
<td>9</td>
<td>202</td>
<td>95</td>
<td>14</td>
<td>5</td>
<td>320#</td>
<td>790.8</td>
</tr>
<tr>
<td>2004-05</td>
<td>13</td>
<td>138</td>
<td>70</td>
<td>10</td>
<td>3</td>
<td>232#</td>
<td>810.1</td>
</tr>
<tr>
<td>2005-06</td>
<td>9</td>
<td>130</td>
<td>75</td>
<td>15</td>
<td>4</td>
<td>233#</td>
<td>825.4</td>
</tr>
<tr>
<td>2006-07</td>
<td>8</td>
<td>95</td>
<td>79</td>
<td>4</td>
<td>8</td>
<td>194</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: @ : Excludes Accidents on Konkan and Metro Railway.

Extracted from IndiaStat.com
Exhibit 14: Number of causalities in train accidents in India

<table>
<thead>
<tr>
<th>Year</th>
<th>Passengers</th>
<th>Railway Staff</th>
<th>Others</th>
<th>Total</th>
<th>Passengers</th>
<th>Railway Staff</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996-97</td>
<td>83</td>
<td>27</td>
<td>253</td>
<td>363</td>
<td>237</td>
<td>84</td>
<td>294</td>
<td>615</td>
</tr>
<tr>
<td>1997-98</td>
<td>171</td>
<td>12</td>
<td>149</td>
<td>332</td>
<td>747</td>
<td>57</td>
<td>195</td>
<td>999</td>
</tr>
<tr>
<td>1998-99</td>
<td>280</td>
<td>15</td>
<td>194</td>
<td>489</td>
<td>615</td>
<td>59</td>
<td>178</td>
<td>852</td>
</tr>
<tr>
<td>1999-00</td>
<td>341</td>
<td>33</td>
<td>242</td>
<td>616</td>
<td>733</td>
<td>77</td>
<td>311</td>
<td>1121</td>
</tr>
<tr>
<td>2000-01</td>
<td>55</td>
<td>8</td>
<td>153</td>
<td>216</td>
<td>286</td>
<td>27</td>
<td>175</td>
<td>488</td>
</tr>
<tr>
<td>2001-02*</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>311</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>681</td>
</tr>
<tr>
<td>2002-03</td>
<td>157</td>
<td>29</td>
<td>232</td>
<td>418</td>
<td>658</td>
<td>41</td>
<td>283</td>
<td>982</td>
</tr>
<tr>
<td>2003-04</td>
<td>135</td>
<td>4</td>
<td>155</td>
<td>294</td>
<td>302</td>
<td>31</td>
<td>159</td>
<td>492</td>
</tr>
<tr>
<td>2004-05</td>
<td>50</td>
<td>5</td>
<td>181</td>
<td>236</td>
<td>191</td>
<td>12</td>
<td>209</td>
<td>412</td>
</tr>
<tr>
<td>2005-06</td>
<td>168</td>
<td>9</td>
<td>138</td>
<td>315</td>
<td>483</td>
<td>31</td>
<td>113</td>
<td>627</td>
</tr>
<tr>
<td>2006-07**</td>
<td>38</td>
<td>6</td>
<td>164</td>
<td>208</td>
<td>227</td>
<td>24</td>
<td>151</td>
<td>402</td>
</tr>
</tbody>
</table>

Note: *: Figures are Provisional.  
**: Excludes KRC and Metro Railway, Kolkata.  
Source: Ministry of Railways, Govt. of India & Rajya Sabha Starred Question No. 35, dated 01.03.2002 and Lok Sabha Starred Question No. 61, dated 18.07.2002.
References


Intelligent Rail Transport Systems


Appendix

Geographic Information System (GIS)
(http://www.gisdevelopment.net/application/Utility/transport/utilitytr0002b.htm)

One common factor between transport, power transmission and telecommunications is that they form a part of the network industry which is geographically spread. Any change in the operating practices of one of the parts has considerable impact on the other. Any improvement measures targeting to improve any one of the systems without involving the other sectors would be able to achieve only sub-optimal results. A point of optimality will be reached if all three are taken into consideration for the strategic modeling of the whole network.

Geographical Information System (GIS) is a kind of spatial technology used for capturing, analyzing and presenting data which is geographically referenced (location). It even allows users to create interactive queries and analyze spatial data.

The enormous growth of transport infrastructure has lead to the demand of spatial data for the effective operational management of its resources as much of the information is location based and geographically referenced. This has led to the emergence of GIS as the optimal technology that can handle such information. And there is a growing opinion among transportation experts that an integrated transportation system should be modeled on the basis of GIS.

Global Positioning Systems (GPS)
The GPS was developed by the US Department of Defence. It is part of the Global Navigation Satellite System (GNSS). It uses a system of about 24 to 32 medium earth orbit satellites to transmit signals to the GPS receivers enabling the users to determine their current location, speed and direction of movement and time.
The system of satellites is maintained by US Air Force 50th Space Wing. The other such systems that are proposed to become operational in near future include GLONASS of Russia, Galileo of Europe, COMPASS of China and IRNSS of India.
(http://www.satnews.com/cgi-bin/story.cgi?number=1908657540)
The Indian Regional Navigational Satellite System (IRNSS), being developed by the Indian Space Research Organization (ISRO), will make use of seven satellites for their navigational services. Of these seven satellites, three will be in geostationary orbit and four in geosynchronous orbit. The Center of Principal Control and ground stations will complement the satellites to ensure integrity in the system. ISRO expects the system to be launched in 2009. When fully functional, it will be able to triangulate the position with an accuracy of 20 meters throughout India and 2000 km beyond its borders.

**Global System for Mobile communication or Groupe Spécial Mobile (GSM)** is the most popular cellular network in the world accounting for about 86% of the global cellular market. The family of related technologies offered by the promoters GSM Association includes GSM, GPRS, EDGE and 3GSM. Its total customers include 2 billion and another 400 million have been added in the past one year.

GSM networks operate in the following four different frequency ranges:

1. 900 MHz or 1800 MHz band: Most of the GSM networks operate in this range.
2. 850 MHz and 1900 MHz: This band is used in some countries including Canada and the US as the 900 and 1800 MHz frequency bands were already allocated.
3. 400 and 450 MHz: This frequency band is rare and is assigned in some countries such as Scandinavia, as these frequencies were previously used for first-generation systems.
4. GSM-900 uses 890–915 MHz for uplink and 935–960 MHz for downlink. The GSM-900 band has been widened in some countries to cover a larger frequency range. This 'extended GSM', E-GSM, utilizes 880–915 MHz for uplink and 925–960 MHz for downlink.

GSM has been used for a variety of other applications. One such application has been the GSM-R for railways. The GSM-R commercial system can support the following services:

I. Control systems where data can be exchanged between the train and track-side traffic control centre
II. voice communication between all the persons involved (Train drivers, track-side personnel, traffic controller )
III. Emergency call handling
IV. communication recording
V. Data messages exchange

General Packet Radio Service (GPRS) Platform
GPRS (General Packet Radio Service) is a wireless data service, accessible now to almost every GSM network. GPRS is an Internet Protocol based connectivity solution and with throughput rates of up to 40 Kbit/s can support a wide range of applications including enterprise and customer. It enables the users to connect to Internet at the speed of 40 Kbits/s but with the added advantage of being able to connect from anywhere. It also supports other features such as multimedia messages, video streaming and location-based services. The adoption of GPRS is big step in the progression towards the 3GSM (or wideband-CDMA) networks and services.