European Journal of Social Sciences Studies
ISSN: 2501-8590
ISSN-L: 2501-8590
Available on-line at: www.oapub.org/soc

DOI: 10.46827/ejsss.v6i2.997 | Volume 6 | Issue 2 | 2021

AWARENESS AND ADOPTION OF INTELLIGENT RAILWAY TRANSPORT SYSTEM IN ZIMBABWE

Leonard Shambira[i],
Memory Mandiudza
Lecturer,
Department of Mathematics and Computer,
Science Great Zimbabwe University,
Zimbabwe

Abstract:
The study seeks to investigate the awareness and adoption of modern technologies which are collectively called (IRTS) Intelligent Railway Transport Systems by the NRZ (National railways of Zimbabwe) of Zimbabwe. Adoption of these technologies are on an increasing trend in developed and developing countries, installation and implementation of a railway system called RailTracker in Tanzania has improved railway services in that country, in Uganda and Kenya the Rift Valley Railway (RVR) has introduced GPS technology to track trains. In India a system is used to detect defects in rolling stock while they are on the run. Where these systems have been implemented, they have significantly improved the efficiency, safety and quality of service of railway operations. In Zimbabwe the rail network is an important transport infrastructure enabling movement of goods and passengers. Primary research was carried out using questionnaires and semi structured interviews, data was collected from 67 participants comprising Engineers, Technicians, Train Drivers and Station Managers. 98% of the technical participants indicated that they were aware of IRTS however the adoption of the systems by the NRZ is at 0%. 100% of the Managers indicated that they were aware of IRTS and the company is willing to adopt them but currently no system has been installed Secondary research was conducted to identify and study similar projects elsewhere, their success as well as the difficulties encountered during their implementation. Secondary data was collected from books and the Internet.

Keywords: intelligent railway transport systems, technology, infrastructure

1. Introduction

Intelligent Railway Transport System is a railway transport system of new era which integrates electronic technology, computer technology, modern communication

[i] Correspondence: email lshambira@gzu.ac.zw

technology, present information processing technology, system and control technology, management and policy support technology and intelligent automation technology on the basis of implementing information collecting, transmission, processing and sharing according to efficient utilization of mobile, fixed, space, period and human resources on railway transportation to ensure safety, raise transportation efficiency, improve management and administration and improve service quality at low cost. (Wang Zhou, 2011)

Zhou also said "*The benefits of developing an intelligent rail system include avoidance of collusions, over speed accidents, terrorist attack monitoring and prevention, increasing transport capacity and assert utilization, protection of passenger service, raising efficiency of energy use and emissions, promotion of economic growth and profits and allowing railway to measure and control, costs as well as dealing with emergency situations*."

The National Railways of Zimbabwe (NRZ) is a parastatal railway of Zimbabwe which runs the railway network in Zimbabwe. The Zimbabwean railway was largely constructed during the time of British colonial rule. NRZ operates about 2700km of railway lines proving passenger and freight services. NRZ has an important transit function in southern Africa and is well linked with neighboring countries namely Mozambique, South Africa, Botswana and Zambia.

The railway industry is largely responsible for the movement of bulk goods especially imports and exports at both regional and international levels thereby promoting regional and international trade. The railroad is facing stiff competition from road freight transport (www.nrz.co.zw).

Figure 1: NRZ Rail Network
(Source: www.nrz.co.zw)

The study was carried out on the Bulawayo, Harare to Mutare railway line. The research was done in Bulawayo, Gweru, Kwekwe, Harare and Mutare.The NRZ network is shown on Figure 1.

2. Aim of the study

To establish the awareness and adoption of Intelligent Railway Transport Systems by the National Railways of Zimbabwe (NRZ).

2.1 Literature review

The Railway Intelligent Transportation System (RITS) is a new generation railway system, which integrates Hi-Tech of various fields, such as electronics, computer, modern communication, state-of–the–art information processing, control systems, intelligent automation, mechanization, management and decision-making by fully and effectively utilizing all the railway transportation related movable and fixed facilities, space, time and the human resources to improve the safety, transportation efficiency, operation and management as well as quality of service at lower cost (Li-min JIA, Ping LI,A-xin NIE, "An introduction to RITS", Chinese railway, 2003)

RITS is the combination of 3C technology, Artificial Intelligence and Railway Transportation Science (A-xin NIE, "Application foreground, architecture and key technologies for RITS", Journal Chinese railway sciences, 2002.1 Vol. 19, No. 1, 1-7)
Overview of RITS is illustrated on Figure 2.

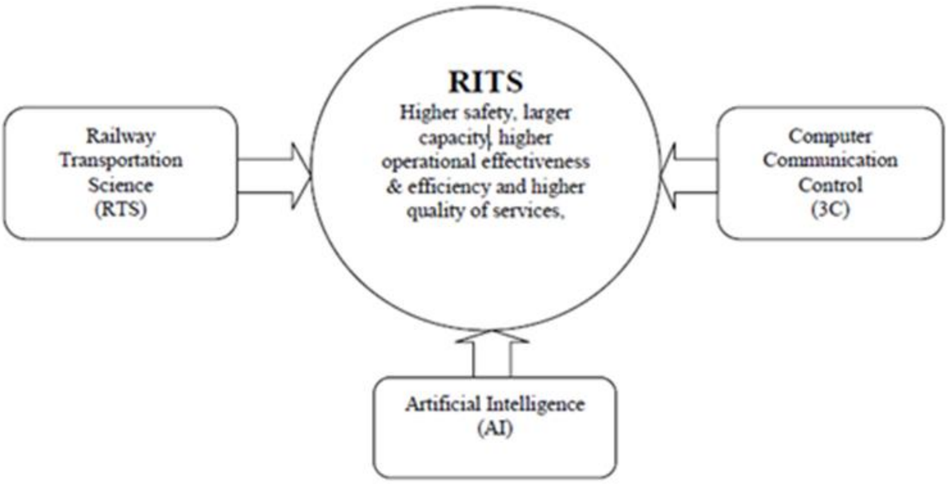


Figure 2: Overview of RITS: Source: Intelligent Automation and Soft Computing

Compared with traditional railway transportation, the characteristics of RITS are as follows: Intelligence, Higher Efficiency, Higher Safety and Higher Quality of Service, Comprehensive optimization, High Coordination of Human, Trains and Lines (Li min JIA and Qiuhua JIANG, "Study on essential characters of RITS", Proceeding of 6th International Symposium on Autonomous Decentralized Systems (ISADS 2003), IEEE Computer Society, Pisa, Italy, April 9-11 2003, pp. 216-221).

Railway Intelligent Transportation System (RITS) will incorporate the new sensor, computer, and digital communications technologies into train control, braking systems, grade crossings, and defect detection, and into planning and scheduling systems as well. And these technologies will prevent collisions and over-speed accidents, provide greater security, increase railroad capacity and asset utilization, improve service to railroad customers, increase railroad energy efficiency, reduce pollutant emissions, enable railroads to measure and manage costs, and increase railroad economic viability and profits (Chaozhe Jiang et al.).

According to Intelligent Transportation America, "*Technology has helped in improving services in many railway companies such as Japan's Tokaido Shinkansen, the most heavily travelled high speed rail line has an annual average delay of 30 seconds France's SNCF manages passenger and freight railways, as well as city buses. They operate 14000 trains per day including the high speed TGV and segments of the Paris and regional transit system. A predictive maintenance system using intelligent sensor is helping SNCF prevent accidents, reduce delays, and cut maintenance costs by an estimated 30 percent.*" (Intelligent Transportation of America, 2010 Annual meeting and conference Houston, Texas May 5, 2010).

2.2 The system architecture of RITS in China

RITS collects, process, and disseminate information automatically to improve transportation safety, security, capacity, and operational effectiveness by incorporating the new sensor, computer, and digital communications technologies into train control, braking systems, grade crossings, and defect detection, and into planning and scheduling systems as well. And establishment of the system architectures is the first step to develop national RITS (Li-min JIA, "The System Architecture of Chinese RITS", Proceedings of Eastern Asia Society for Transportation Studies, Vol. 5, pp. 1424-1432, 2005.) The architecture defines the functions that must be performed to implement a given user service, the physical entities where these functions are, the interfaces, information flows between the physical systems and the communication requirements for the information flows. Its objective is to combine the practical characteristics of the railway transportation system in China and to provide evidence and guidance for planning, design, implementation, standard and management for the RITS with Chinese characteristics (Li min JIA, "The Framework of China Rail Transportation System", Report of China Academy of Railway Sciences, March 2003, pp. 1-5) According to researches done by Prof. Li-min Jia, Qin Yong and Zhang Yuan, the system architecture of RITS is usually divided into the Service Architecture, the Logical Architecture, the Physical Architecture, and the architecture for common platform of RITS.

The architecture of RITS is usually composed of 5 layers, which are perception layer, communication layer, integration layer, operation layer and service layer (Ping Li, Li-Min Jia, "Study on the Standard Architecture of RITS", China-Japan-Korea Cooperation research session, 2004.6, Korea), Figure 3 shows the RITS architecture. In the perception layer, the real-time data of the moving trains, the fixed structure and the environment can be captured and stored with the help of advanced sensors, cameras, detecting loop and so on. Communication layers can transfer the data from the communication layer between vehicles and ground equipment, and also among themselves, by using wireless or cable communication. After data transfer, the communication layer will be able to provide the data to the upper integration layer. With the development of distributed computing, data integration and visualization technology, it becomes easy to integrate process and display data in the integration layer so as to provide support for management and decision-making of the operation layer. Based on the information from the integration layer, the operation layer can perform transportation organization; status monitoring and maintenance of the railway system, thus providing strong support for the service layer (Ping Li, Li-Min Jia, "Study on the Standard Architecture of RITS", China-Japan-Korea Cooperation research session, 2004.6, Korea, F.-Y. Wang and S. Tang, "Artificial Societies for Integrated and Sustainable Development of Metropolitan Systems," IEEE Intelligent Systems, vol. 19, no. 4, 2004, pp. 82–87.) The service layer corresponds with the demand and supply of the railway systems. The transportation need from passengers and freight can push the service level to a certain height under the current situation of the railway operation and transportation resources.

Modern digital control systems provide the ability to independently control all aspects of operating a model railway using a minimum of wiring. (Li-min JIA, "The System Architecture of Chinese RITS", Proceedings of Eastern Asia Society for Transportation Studies, Vol. 5, pp. 1424-1432, 2005.) Control is achieved by sending a digital signal down the rails. These digital signals control operation of some, or even all aspects, of the model trains and accessories, including signals, turnouts, level crossings, cranes, turntables, and so forth. With the help of high-capacity communication networks, data fusion and visualization, the functions of the digital railways can be realized, which are coordination and optimization of railway resources and business process. In intelligent railway system, more technologies, such as control and optimization, knowledge reasoning and decision support will be applied. After taking into consideration of the service from passengers and freight, the intelligent railway system can be moved up to RITS. (Li-min Jia, "The System Architecture of Chinese RITS", Proceedings of Eastern Asia Society for Transportation Studies, Vol. 5, pp. 1424-1432, 2005, Ping Li, Li-Min Jia, "Study on the Standard Architecture of RITS", China-Japan-Korea Cooperation research session, 2004.6, Korea).

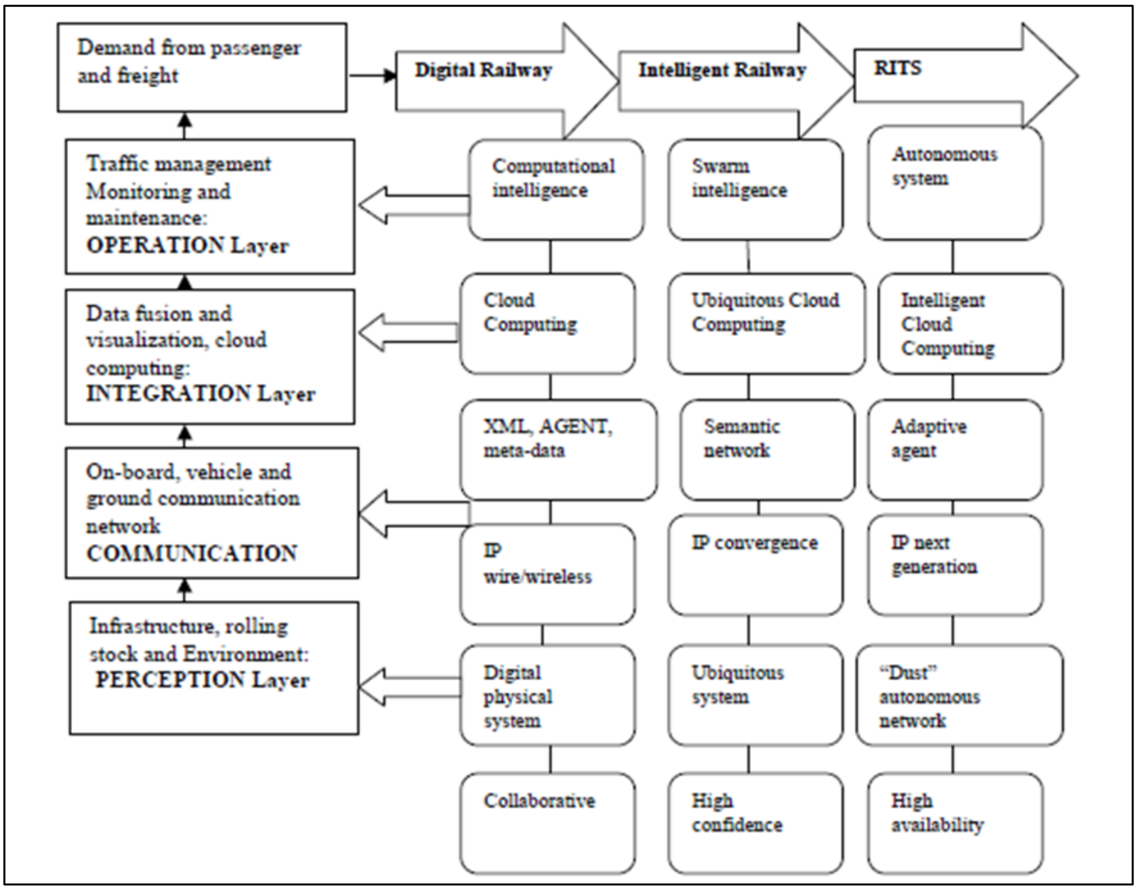


Figure 3: RITS Architecture: Source: Intelligent Automation and Soft Computing

As it can be seen from the above analysis, several key technologies in RITS are internet of things, high-capacity communication, cloud computing and interoperability, knowledge reasoning and network security, which provide support for perception layer, communication layer, integration layer operation layer and the whole system separately. (Li-min Jia, "The System Architecture of Chinese RITS", Proceedings of Eastern Asia Society for Transportation Studies, Vol. 5, pp. 1424-1432, 2005, Li min Jia, "The Framework of China Rail Transportation System", Report of China Academy of Railway Sciences, March 2003).

Apart from the technologies mentioned above, the security of the network communication and wireless networks cannot be neglected as well. RITS Network Security consists of a variety of public and private computer networks, which are used in everyday transactions and communications among businesses, government agencies and individuals. And the data security, communication security, running security and operation security should be maintained so as to achieve the goals of higher safety, higher efficiency and higher service quality (Chaozhe Jiang et al.).

2.3 Intelligent Railroad Systems in the United States of America

In the United states of America Intelligent railroad systems were first described in the Secretary of Transportation's report, The Changing Face of Transportation, published in 2000, and were expanded in the Federal Railroad Administration's (FRA's) Five-Year Strategic Plan for Railroad Research, Development, and Demonstrations, a report to

Congress was published in March 2002. The FRA, railroads, and the railroad supply industry have been working on the development of intelligent railroad systems for command, control, communications, and information (C3I), as well as for braking systems, grade crossings, defect detection, and planning and scheduling systems. These technologies can prevent collisions and over speed accidents, prevent hijackings and runaways, increase capacity and asset utilization, increase reliability, improve service to customers, improve energy efficiency and emissions, increase economic viability and profits, and enable railroads to measure and control costs and to "*manage the unexpected*." (Weick, Karl E. and Kathleen M. Sutcliffe, Managing the Unexpected, San Francisco: Jossey-Bass, 2001). Intelligent railroad systems will enable railroads to improve their responsiveness to military deployments and to respond with flexibility and agility to rapid changes in the transportation marketplace.

Following the terrorist events of 9/11 2001, and especially following the terrorist bombings of trains in Madrid, Spain, on 3/11 2004, railroad security has received increased attention. Intelligent railroad systems will enable railroads to prevent some types of terrorist incidents from occurring, and, should incidents occur, these technologies will enable railroads to detect them, notify appropriate authorities, and recover more rapidly from the incidents. Railroads will have continuous, real-time information with which they can manage their operations (Ditmeyer, 2010).

2.4 Network-Centric Railroading and the Intelligent Railroad Systems

Network-centric railroading is a "system of systems." It has 29 technologies, programs, and systems, either developed or under development, which comprise intelligent railroad systems. Figure 4 illustrates a preliminary architecture for network-centric railroading, showing how the intelligent railroad systems fit together and identifying the key communications links for standardization. It is a top-level interconnect diagram and is based on conventions developed by the Architecture Development Team for the ITS National Architecture. This type of diagram is known as a "sausage diagram" in which the "sausages" represent the various communications links that move information between nodes in the gray rectangles representing crews and vehicles, fixed installations along the railroad rights-of-way, control and management centers, and customers. The links can be owned by railroads or by commercial telecommunications carriers and they can be microwave radio, fiber optic cable, buried copper cable, cellular telephones, communications satellites, traditional pole lines, and the Internet (Ditmeyer, 2010).

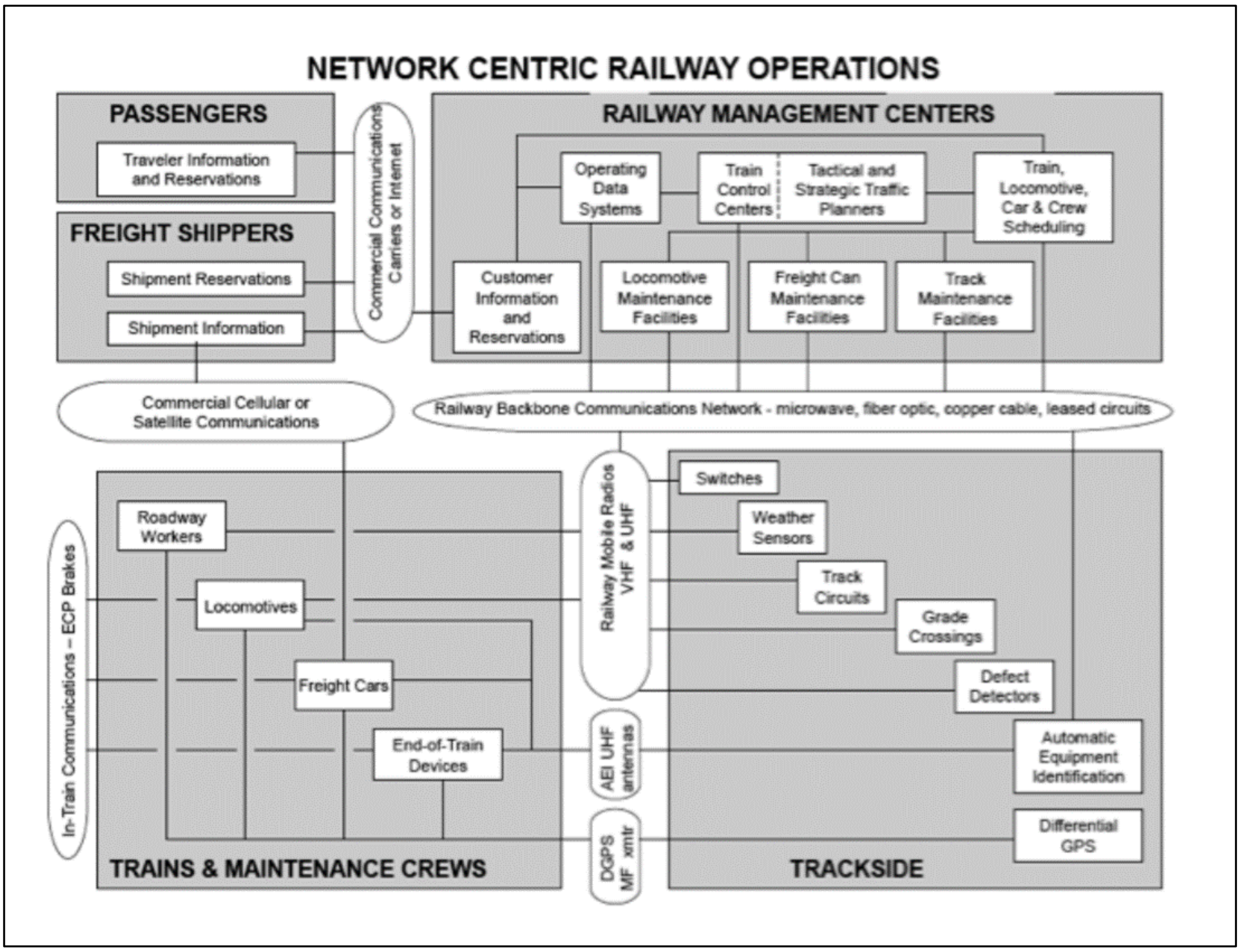
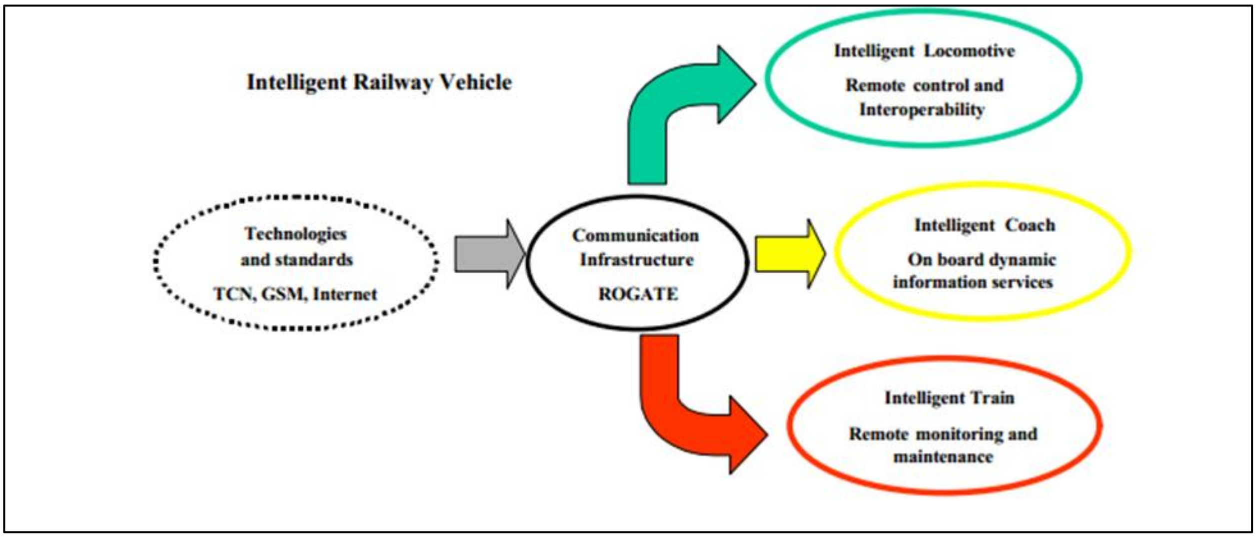


Figure 4: Architecture of Network-Centric Railroading
(Source: United States of America Department of Transport)

2.5 Intelligent Rail Transport Systems in Europe

Trains in Europe use a digital network standard called Train Communication Network (TCN) which allows interoperability between train equipment and devices from different manufacturers located on board the same train as shown on Figure 5.



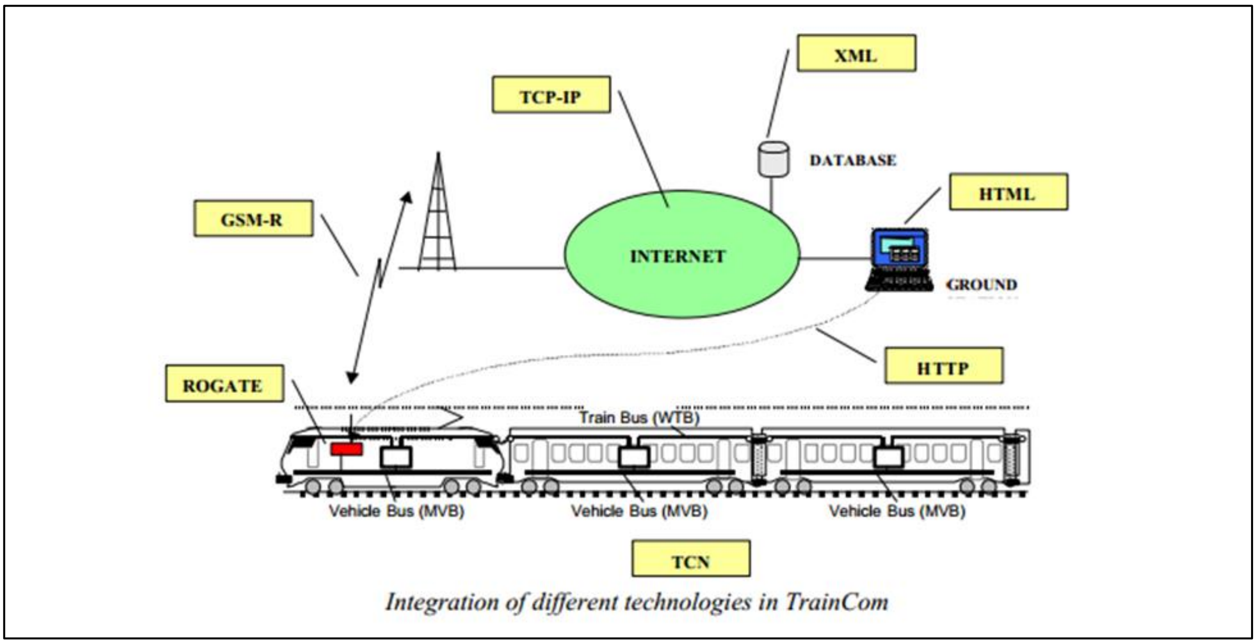


Figure 5: Integration of different technologies in TrainCom
(Source: www.traincom.org)

This system will ensure that passengers have at their disposal the latest information on destinations, routes, delays, platform arrivals and connections. Furthermore, reservation data will be uploaded to the train directly from ground office, thus reducing the time limit for reservations before train departure and assuring that updated information is available on board, for passengers to find or check their seats (www.traincom.org).

TrainCom aims to integrate the already established onboard communication network with a newly developed ground system that makes use of a railway version of the radio link GSM (global system for mobile communications). Using Internet solutions such as extensible markup languages (XML) and the standard Internet protocol (TCP-IP), messages can be quickly relayed to and from ground control databases and applications. It is expected that offering this kind ubiquitous remote access to onboard equipment will bring about a new standard platform, on top of which a number of applications can be built, such as passenger information, remote monitoring, maintenance and remote control. In real terms, such applications are certain to make railway travel in Europe more efficient. It means that passengers will have at their disposal the latest information on destinations, routes, delays, platform arrivals and connections. Furthermore, reservation data will be uploaded to the train directly from a ground office, thus reducing the time limit for reservations before train departure and assuring that updated information is available on board, for passengers to find or check their seats (http://www.traincom.org).

2.6 RailTracker

In Tanzania, the Tanzanian Railways Corporation (TRC) uses a system called RailTracker in managing its rail services. RailTracker is a computerized wagon, locomotive train reporting system that tracks cargo and wagons throughout their movement. It thus increases the efficiency of freight operations, enabling railways to plan the movement of wagons much more effectively since they always know where the wagons are and whether the wagons are empty, loaded and fit for running. This improves short term train planning since it is possible to know when empties will be available, and enables rolling stock and motive power to be maintained on the basis of up to date records of equipment use. RailTracker also enables the railways to satisfy customer's request for information about the whereabouts of their goods at any given time. In addition it generates statistics and performance indicators for decision marking (UNCTAD).

2.7 Intelligent Railway Transport Systems in Kenya and Uganda

In Kenya and Uganda Rift valley railways is using technology similar to that used on railways in Brazil, Argentina, South Africa and Japan, this technology is expected to bring the 1,461-mile Kenya-Uganda Railway into the modern era of railway management, according to a report in www.AfricaReview.com.

3. Methodology

The methodology seeks to come up with ways to collect data and obtain results. As a result, the research design, data collection instruments, data collection process will be highlighted. Justifications for selected research methods will also be included.

3.1 Research Design

According to Kumar (2001:70), "*a research design is a detailed blue print used to guide a research study towards its objective*". This study employed exploratory and descriptive research designs.

3.2 Exploratory research

Exploratory research, according to Malhotra (2007), is used to provide insights into, and an understanding of the problem confronting the researcher. This research design enabled the researcher to gain ideas and insights into the general awareness and adoption of Intelligent Railway Transport systems by the National Railways of Zimbabwe. It enabled the researcher to identify relevant variables that were to be considered. The insights gained from the research design were verified or quantified by the descriptive research design. That is the basic purpose of exploratory research was to provide information to assist in research.

3.3 Descriptive research

Descriptive research involves gathering data that describe events and then organizes, tabulates, depicts and describes the data collected. (Glass & Hopkins, 1984). Descriptive studies are aimed at finding out "what", so observational and survey methods are frequently used to collect descriptive data. (Bog & Gall, 1981). The research was done in Bulawayo, Gweru, Kwekwe, Harare, and Mutare and considered responses from Engineers, Technicians, Train Drivers and Station Managers.

Descriptive research is also preplanned and structured as a result it specifies the methods for selecting the sources of information and for collecting data from the sources. As a result, it enabled the researcher to get information from secondary sources and primary sources as well as to use questionnaires and in-depth interviews in evaluating the awareness and adoption Intelligent Railway Transport Systems by the National Railways of Zimbabwe.

The main purposes of research are to describe, explain and validate findings. Description emerges following creative exploration and serves to organize the findings in order to fit them with explanations and then test or validate these explanations. (Krathwohl, 1993) The descriptive function of research is heavily dependent on instrumentation for measurement and observation (Borg & Gall 1989).

3.4 Research instruments

The researcher used thoroughly validated questionnaires and interviews as instruments that yielded valuable descriptive data. The researcher administered both structured and unstructured interviews. The researcher also used secondary data. The researcher carried out a pilot test of the research instruments to ensure their reliability. The purpose of pre-testing (pilot test) is to ensure that the questions are clear and meaningful. Pretesting ensures that the questions used to collect data will measure up to the intended concepts and values.

3.5 Sampling frame

Table 1: Sample frame of the target population

	Bulawayo	Gweru	Kwekwe	Harare	Mutare	Total
Train Drivers	4	3	2	3	2	14
Engineers	3	1	0	2	1	7
Technicians	9	11	2	10	9	41
Station Managers	1	1	1	1	1	5
Total						**67**

3.6 Data analysis

A total of 70 questionnaires were distributed to Engineers, Technicians and Train drivers. The same sets of questions were distributed to Engineers, Technicians and Train Drivers because these are the technical people who understand and use technology in their day to day operations in the National Railways of Zimbabwe. Out of a total of 70 questionnaires that were administered 62 of them responded in which there was a response rate of 86%. The non-response rate was in the acceptable range as indicated by Dixon et al (1987), in their research, 'rules of thump' that non response rate for any research should not exceed 33%. Semi structured interviews were conducted on 5 managers and there was a 100% response rate. It was observed that the majority of the participants 61% were Technicians and the majority being male constituting 90%.

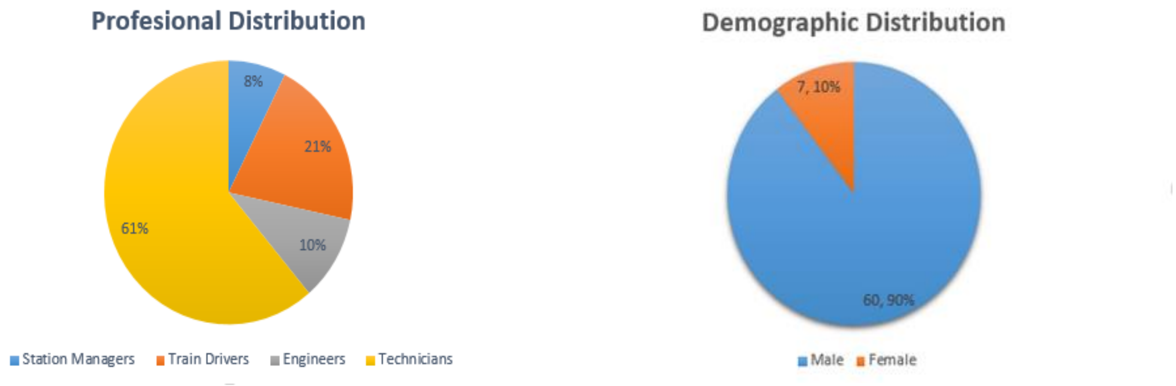


Figure 6: Professional and Demographic Distribution

3.7.1 IRTS Awareness question

Are you aware of new technologies which are being used in modern Railways which are collectively called Intelligent Railway Transport Systems? (IRTS)

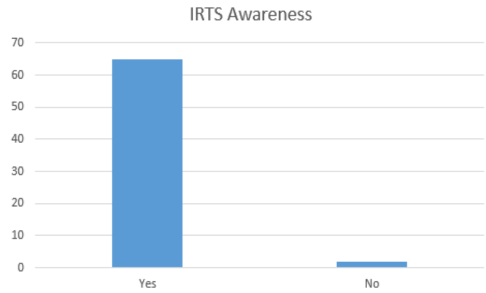
Yes. ☐ No. ☐

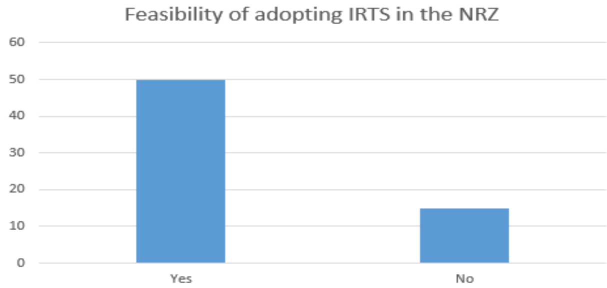
If your answer to this question is yes, briefly explain if it's feasible or not feasible to integrate these technologies with existing infrastructure being used in the the National Railways of Zimbabwe

----

98% of the technocrats indicated that they were aware these technologies which are being used in modern Railways which are collectively called Intelligent Railway Transport Systems (IRTS) and 2% did not know the existence of intelligent Railway Transport Systems. All participants indicated they were aware of the Global Position Systems (GPS). They indicated that the NRZ is using GPS to track goods trains but the system is having some technical challenges and is not performing according to expectations. The finding indicated that the majority of the technical personnel in the NRZ are aware of Intelligent Railway Transport Systems (IRTS) and participants who are aware of the existence of IRTS 76% indicated that it is feasible to implement IRTS, and 24% indicated that it is not feasible. The 24% who indicated that it is not feasible cited the following reasons.

- The NRZ does not have the financial capacity to implement the project.
- Signaling infrastructure has been vandalized such that it will be costly to implement the project.
- There is no technical expertise to implement and support the system.
- Existing infrastructure cannot support IRTS.





3.7.2 IRTS adoption Question

Has the NRZ adopted any form of Intelligent Railway Transport System?

Yes. ☐ No. ☐

If your answer to this question is yes, briefly explain the technologies adopted by the NRZ.

All the participants indicated that there is 0% adoption of IRTS systems in the NRZ.

3.8 Analysis of response from managers

Semi structured interviews were administered to NRZ Managers. These interviews were meant to look at policy issues and the financial status of NRZ. All NRZ mangers are aware of IRTS but the company has not adopted any of these technologies.

90% of the Managers agreed that modern technology can improve NRZ service delivery while 10% had the opinion that NRZ should first improve its infrastructure both its rolling stock and rail tracks. They believed that technology should be implemented on a sound infrastructure. The 10% also highlighted that technology should be implemented on an incremental basis not as a big bang.

All the Managers said the technology being used by the NRZ is absolute and need to be decommissioned and pave way for new technology so as to improve on safety, efficiency and effectiveness. They also said NRZ has introduced GPS to track its freight but the technology is not operating according to expectations because it is SMS based.

100% of the Managers said NRZ is willing to implement new technology in its operations but NRZ has financial challenges, NRZ does not have the financial capacity to implement these technologies, but it has the technical capacity. NRZ will prefer a build – operate and transferee situation. They also proposed for the unbundling of NRZ into two entities namely infrastructure and operations.

80% of the Managers said vandalism of NRZ infrastructure is a well-coordinated job by some NRZ employees. They highlighted that new technology should be installed on railway infrastructure which can aid in detecting any form of vandalism. They also suggested that staff should be paid on time so as to boost their moral. When moral is high acts of sabotage and vandalism can be minimized. They also suggested that in future NRZ should use aluminum cables as overheard cables for electric trains because aluminum does not have a ready market as copper.

4. Conclusions

The study revealed that the NRZ is aware of IRTS and its benefits however the NRZ has not adopted any of these technologies due to financial constraints. The company is proposing a build operate and transfer option to finance the project since its infrastructure has dilapidated and its revenue has deteriorated due to the collapse of Zimbabwe heavy industry. The NRZ used to be the major transporter of raw materials to heavy industries but these industries have closed or scaled down operations due to decades of economic meltdown which resulted in its revenue dropping.

Benefits of IRTS can be summarized as:

- Intelligence,
- Higher Efficiency,
- Higher Safety,
- Higher Quality of Service,
- Comprehensive Optimization,
- High Coordination of Human, Trains and Lines.

The study also revealed that modern technology such as IRTS can help in improving service delivery in the NRZ. This was based on secondary data collected from other railway companies such as Tanzania Railway where a system called RailTracker has brought tangible benefits to Tanzania Railways. Intelligent Railway Transport Systems have also increased the efficiency, effectiveness and safety of railway systems in China, Uganda, Kenya and India as was stated in the literature review.

4.1 Recommendations

Once the financial heddle is accomplished the National Railways of Zimbabwe should consider installing an Intelligent Railway Transport System. This system can be installed on the existing infrastructure. NRZ has a very good microwave link, thus this link can be used as a backbone for transmission of data to be used in the Intelligent Railway Transport System. These systems are tried and tested hence there is no need for research and development. What is only needed is find renowned suppliers who can install operate and transfer the system at a later date. The installation of this system will increase the efficiency, effectiveness and safety in the operations of NRZ. Intelligent systems can also minimize acts of vandalism since the system can report these acts in real time so that the authorities can act in a timely manner.

Conflict of Interest

The authors declare that there is no conflict of interest.

About the Authors

Leonard Shambira is a lecturer in the department of Mathematics and Computer Science at Great Zimbabwe University.

Memory Mandiudza is a lecturer in the department of Mathematics and Computer Science at Great Zimbabwe University.

References

Alberts, David S. et al., Network Centric Warfare: Developing and Leveraging Information Superiority, Washington, DC: Department of Defense (DOD) Command and Control Research Program, 1999.

Alford, Kenneth L. and Steven R. Ditmeyer, "Network-Centric Operations: Defense and Transportation Synergy," Crosstalk: The Journal of Defense Software Engineering, January 2007.

A-xin Nie, "Application foreground, architecture and key technologies for RITS", Journal Chinese railway sciences, 2002.1 Vol. 19, No. 1, 1-7.

Bin Wang, Qing Chao Wei, Qulin Tan, Shonglin yang, Baigen cai. Intergration of GIS, GPS and GSM for the Qinghai-Tibet railway Information management Planning 2004

Casey, R., et. al., Advanced Public Transportation Systems: The State of the Art - Update '96, USDOT FTA, January 1996.

Ditmeyer, Steven R. and Michael E. Smith, "Data Links and Planning Tools: Enhancing the Ability to Plan and Manage Train Operations," Rail International, April 1993.

Dr Praveen Kumar, Dhanunjaya Reddy and Varum Singh. Intelligent Transport Systems using GIS 2008

E. Renner, P. Umiliacchi: "TrainCom: an Integrated Communication System for Intelligent Train Applications" – WCRR '03 – World Conference on Railway Research Edinburgh, Scotland – 28 September - 1 October 2003.

F.-Y. Wang and S. Tang, "Artificial Societies for Integrated and Sustainable Development of Metropolitan Systems," IEEE Intelligent Systems, vol. 19, no. 4, 2004.

F.-Y. Wang and S. Tang, "Artificial Societies for Integrated and Sustainable Development of Metropolitan Systems," IEEE Intelligent Systems, vol. 19, no. 4, 2004.

Florian Fuchs, Sebastian Henrici, Michael Pirker, Michael Berger, Gerhard Langer, Christian Seitz: "Towards Semantic-based Monitoring of Large-Scale Industrial Systems" – CIMCA-2006 – International Conference on Computational Intelligence for Modelling, Control and Automation, Sydney – Australia – 28 November - 1 December 2006.

Intelligent Transportation of America Annual Meeting, 2005.

IRSE Seminar on role of modern Signaling, Telecom & ICT system in marking IR a world class rail network.

Japan Highway Industry Development Organization, "ITS Handbook Japan 2007-2008."

Jasper Dekkers and Piet Rietveld 2007. Journal of Intelligent Transportation Systems.

Kaplan, Jeremy, A New Conceptual Framework for Net-Centric, Enterprise-Wide, System-of-Systems Engineering, Defense & Technology Paper 30, Center for Technology and National Security Policy, National Defense University, June 2006.

L. Li et al., "IVS 05: New Developments and Research Trends for Intelligent Vehicles," IEEE Intelligent Systems, vol. 20, no. 4, 2005.

Li min Jia and Qiuhua Jiang, "Study on essential characters of RITS", Proceeding of 6th International Symposium on Autonomous Decentralized Systems (ISADS 2003), IEE Computer Society, Pisa, Italy, April 9-11 2003.

Li-min Jia, "History, intelligence and automation in railway transportation--the arts of the state and development", CDC'96, science publishing company, 1996.

Li-min Jia, "The Framework of China Rail Transportation System", Report of China Academy of Railway Sciences, March 2003.

Li-min Jia, "The System Architecture of Chinese RITS", Proceedings of Eastern Asia Society for Transportation Studies, Vol.5.

Li-min Jia, Ping Li, A-xin Nie, "An introduction to RITS", Chinese railway, 2003.

Luo, Q., 2008. Research on Intelligent Transportation System Technologies and Applications. in Power Electronics and Intelligent Transportation System, PEITS '08. Workshop 2008.

National Railways of Zimbabwe. (2021). Retrieved 6 February 2021, from https://nrz.co.zw/.

P. Umiliacchi, R. Shingler, G. Langer, U. Henning: "A new approach to optimization through intelligent integration of railway systems: the InteGRail project" - WCRR '06 –World Conference on Railway Research – Montreal, Canada – 4-8 June 2006.

P. Umiliacchi: "The role of European Research in the railways modernization process the ROSIN (Railway Open System Interconnection Network) project" – WCRR '97 - World Congress on Railway Research – Florence, Italy - 16-19 November 1997.

Ping Li, Li-Min Jia, "Study on the Standard Architecture of RITS", China-Japan-Korea Cooperation research session, 2004.6, Korea.

Ping, Li-Min SIA, A-Xin Nie. Study on Railway Intelligent Transport System Architecture 2006

R. Lu, D. Zeng, and F.-Y. Wang, "AI Research in China: 50 Years down the Road," IEEE Intelligent Systems, vol. 21, no. 3, 2006.

R. Shingler, P. Umiliacchi: "Advances in railways maintenance: the EuRoMain project" – WCRR '03 – World Conference on Railway Research – Edinburgh, Scotland – 28 September - 1 October 2003.

Railway Ministry of China, "The Long-Term Railway Development Plan in China", Chin Railway Press.

Ramazan Demu, Ichiro Masak and Edward F. Crawley. System Design for Intelligent Railway Systems

Richard Lewis, Florian Fuchs, Michael Pirker, Clive Roberts, Gerhard Langer: "Using Ontology to Integrate Railway Condition Monitoring Data" – RCM-2006 IET International Conference on Railway Condition Monitoring - Birmingham – UK – 29-30 November 2006.

S. Tang, F.-Y. Wang, and Q. Miao, "ITSC 05: Current Issues and Research Trends," IEEE Intelligent Systems, vol. 21, no. 2, 2006.

Saurabh Amin, et al., "Mobile Century—Using GPS Mobile Phones as Traffic Sensors: A Field Experiment," University of California Berkeley, February 2008, http://traffic.berkeley.edu/conference%20publications/Mobile_Century.pdf.

Smith, H. R., B. Hemily and M. Ivanovic, 2005. Transit signal priority (TSP): A planning and implementation handbook.

Stefan Konig and Eckehard Schnieder 2001 IEEE Intelligent Transport Systems Conference Proceedings. Modeling and Simulation of an Operation Concept for Future Rail Traffic

The ITS National Architecture, developed by the ITS Joint Program Office, US DOT.

The Theory and Method of Design and Optimization for Railway Intelligent Transport Systems Wang Zhou, Jia Li-Min 2011.

TrainCom. (2021). Retrieved 6 February 2021, from http://www.traincom.org/

U. Henning, R. Shingler, P. Umiliacchi, G. Langer: "Managing traction data according to a standardised approach: the InteGRail project" – RTS 207 – Rail Traction System – Tokyo, Japan – 12-15 November 2007.

U. Zahner, "Information Technologies in support of Maintenance: EuRoMain –European Diagnostic Data Network EDDN", EuroMaintenance 2004, Barcelona, Maintenance and Sustainability Session – 11-13 May 2004.

UNCTAD. (2021). Retrieved 6 February 2021, from https://unctad.org/

Wei Xu, Yong Qin and Houkuan Huang. The application of Spatial Data Mining in Railway Geographic Information System, 2008.

Yasutaka Maki. Railway Technology avalanche number 9 August 2005. A New Train Position detection System Using GPS.