

INTEGRATION OF GIS, GPS AND GSM FOR THE QINGHAI-TIBET RAILWAY INFORMATION MANAGEMENT PLANNING

Bin Wang^a, Qingchao Wei^a, Qulin Tan^a, Shonglin Yang^a, Baigen Cai^b

^a School of Civil Engineering & Architecture, Beijing Jiaotong University, Beijing 100044, China - jwpeng@sina.com

^b School of Electronics and Information Engineering, Beijing Jiaotong University, Beijing 100044, China –
bgcai@center.njtu.edu.cn

KEY WORDS: Management, Planning, Integration, GIS, GPS

ABSTRACT:

The Qinghai-Tibet Railway is a key project during China's Tenth Five-Year Plan period. It will be the longest and most elevated railroad built on highlands in the world. The construction and transport conditions are so complicated, such as permafrost, bitter coldness, lack of oxygen and ecological fragility. Therefore advanced technical measures and methods have been used during the construction. Furthermore, we have carried out Qinghai-Tibet Railway information management planning (QTIMP) based mainly on the G3 technique integration: geographic information system (GIS), global positioning system (GPS), and global system for mobile communication (GSM) to ensure safe transportation and prompt maintenance of Qinghai-Tibet Railway. The paper is focused on the latter. In this paper, we briefly introduces Qinghai-Tibet Railway project, emphasizes the need of QTIMP in section one. Section two gives an overview of the G3 technique integration. Section three describes the architecture of QTIMP. Section four primarily deals with the applications of G3 technique integration to QTIMP. In this section the paper is mainly focused on the visualization of geographical information at a control centre, on the design of the on-board unit and on the interaction and communication between on-board units and the control centre. Finally, a brief discussion leads to conclusions and some key issues for future research.

1. INTRODUCTION

The Qinghai-Tibet is a key project in the China's Tenth Five-Plan (2001-2005) period. The railway starts at Xining (the capital of Qinghai province), and terminates Lhasa (the regional capital of Tibet), with a total length of 1,956km. The first 814km section from Xining to Golmud, a traffic hub in the western part of Qinghai province, opened to traffic in 1984. In the second part of the project, a 1,142km-long new line (called Golmud-Lhasa section) consists of the 32km section from Golmud to Nanshankou to be upgrade and the 1,110km Nanshankou-Lhasa to be built. The new line opened to construct in June, 2001, and is due to enter service in 2007. It is the first railroad to Tibet. The building of this line is of major political and economic significance. It will contribute substantially to fostering local market development, creating jobs and bringing new opportunities for the regions along the line.

The Golmud-Lhasa section is a mountainous section running through the Qinghai-Tibet Plateau. The construction and transport conditions are so complicated, such as permafrost, bitter coldness, lack of oxygen and ecological fragility, etc. Permafrost (thawing and subsidence, freezing and swelling) affects the stability and safety of railway engineering structures and lead to uneven subsidence. Lack of oxygen not only affects people's health and productivity, but also reduces the performance of diesel locomotives and engineering equipment. To overcome the particular topological conditions of Tibet, it is firstly vital to guarantee the health and safety of the constructors, railway operating staff and the travelling public by using modern safety installations. Secondly, the building machinery and operating equipment must be specially designed for working in high mountain areas. Thirdly, the operating system must be adapted to the highland conditions. Therefore, advanced technical measures and methods have been used

during the construction (Tsai, S., 2003). Meanwhile, we have carried out QTIMP based mainly on the G3 technique integration to ensure safe transportation and prompt maintenance of Qinghai-Tibet Railway.

2. G3 OVERVIEW

G3 integrates three system technologies: geographic information system (GIS), global positioning system (GPS), and global system for mobile communication (GSM) to provide an extremely accurate location-tracking system.

2.1 GIS

GIS, a set of software tools, allows analysis of different data types to be linked to geographic maps. This technology includes input tools, a database management system, queries, analysis, visualization tools, and a graphical user interface. GIS stores attribute information as a collection of thematic layers linked together by spatial information. Users can perform common database operations such as queries and statistics, and view the results in geographic maps (Samah et al., 2000). A GIS usually provides a number of tools for the analysis of spatial networks (e.g. railroad networks).

2.2 GPS

GPS is a satellite navigation system operated by U.S. Department of Defence. The overall GPS system includes 24 navigational orbiting satellites, six earth control stations, and thousands of user-owned receivers. Positioning signals originating from 24 satellites are distributed in such way that at least four of them are visible from any point of the earth. The satellites transmit time information derived from their internal atomic clocks along with data on their momentary positions. A

GPS receiver can convert satellite signals into position, velocity, and time estimates. After the White House removed the intentional degradation of GPS signals, civilian GPS receivers are accurate to within less than 20m, ushering in an exciting time for GPS applications like location-tracking systems.

2.3 GSM

GSM is a digital cellular communication system that prevails throughout Europe and much of the rest of the world. At present, cellular communication system has become a new trend for many varieties applications, especially railway application (called GSM-R). GSM system is divided into three parts: mobile station, base station subsystem and network subsystem. At present, the commercial GSM-R rail communication systems can provide all the services required:

1. Train control systems, where data exchange between trains and track-side traffic control centre is required
2. Voice communication between all users (train drivers, traffic controller, track-side workers, train personnel)
3. Emergency call handling
4. Data messages exchange
5. Communication recording
6. Integration with other existing (or future) systems

3. QINGHAI-TIBET RAILWAY INFORMATION MANAGEMENT PLANNING

Railway management information system is a complicated great system. The QTIMP includes six systems (Lu et al., 2003), shown in figure 1, which are:

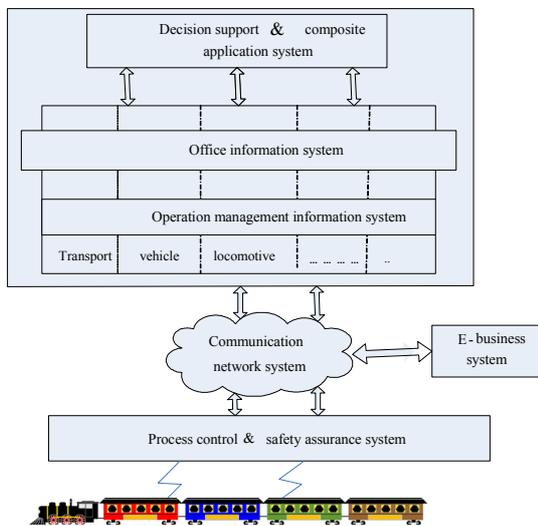


Figure 1. Qinghai-Tibet railway information management planning architecture

3.1 Communication Network System (CNS)

It transmits data, voice, even image information among the systems. It provides a platform for information exchange.

3.2 Operation Management Information System (OMIS)

It is designed for different level of managers from different management sector as passenger/freight transport sector, locomotive sector, etc. It can assist managers to rapidly acquire, deliver, and use information, further, provide aided design.

3.3 Process Control & Safety Assurance System (PCSAS)

It ensures on-line vehicles safe. It collects data, monitors the work status of equipments, even timely alerts or alarms when irregular cases arise. On the one hand, data about on-line equipment are transferred to OMIS, on the other hand, commands from OMIS are taken and the work status equipments controlled are made to the high point.

3.4 Office Information System (OIS)

It is designed for the different level of administrators. It supports office tasks done by computer, accelerate information delivery, thus makes office management more effective, In addition, OIS is linked with OMIS, providing information communication between both of them.

3.5 Decision Support & Composite Application System (DSCAS)

It is an intelligent system based on the operation management information system. It can provide top managers with intelligent services and decision support. It consists of computer-aided plan devising, decision support system, and expert system, etc.

3.6 E-business System (ES)

It can buy and sell goods and services on the internet, facilitating inter and intra-organization flow of goods, services, information, communication, and collaboration. It also provides customer service as information consultation, seat reservation and selling, etc, on the internet.

4. APPLICATION TO QTIMP OF THE G3 INTEGRATION

According to the design of the line, there are only 5 pairs of passenger train, about 80 million tons freight in the upward direction (from Lhasa to Xining), and 210 million tons freight in the downward direction (from Xining to Lhasa). The Qinghai-Tibet line is a low traffic rail line. There are long-block sections (about 60km) and few stations along the Qinghai-Tibet line, so the central traffic control is used (Tao, et al., 2003). For the low traffic Qinghai-Tibet rail line under the particular conditions, the advanced technologies should be used to simplify the structure of the vehicle control system, to reduce especially trackside equipment, thus to ensure train system high safety, high reliability and less maintenance. G3 integration used by the QTIMP can meet above demands:

1. A system for displaying the information
2. A system for locating the position of a vehicle
3. A system for transmitting the information to a control centre.

4.1 Control Centre with GIS-based Terminals

The control centre system provides two-way messaging between the on-board units and a central centre. On the one hand, the control centre can not only receive data from the on-board units, but also send a command to an on-board system, or even reprogram it remotely. The frequency of status message delivery, and other parameters controlling communication can also be changed remotely by the centre operator. On the other hand, Irregular situation and emergency calls from the On-board units

can be timely sent to the control centre. The control centre design is shown in Figure 2.

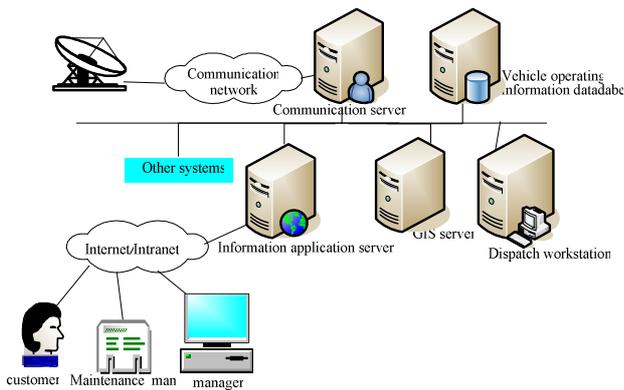


Figure 2. Control centre design

The control centre stores messages in the database, which consists of spatial, attribute and graphical data. The GIS-based operator interface presents a digital map of the rail line and display locations uploaded by each on-board unit onto this map. The operator can change the area displayed and zoom in on any particular section of the railroad line to predetermined resolution. The locations for which alert/alarm conditions are reported will be clearly differentiated on the map with specific icons. The operator can see data content of any particular message by clicking the message icon on the map. The operator can use different queries in order to display on the interface only the information that the operator needs, for example, the operator can specify type of message to be displayed, vehicles of interest, time interval, and so on. In addition to the geographical map based display, the users have access to various reports generated automatically from the database (Lin et al., 2002; Derekenaris et al., 2001).

4.2 On-board Unit with GPS and Wireless Communications

The on-board unit consists of communication satellite antennae, satellite positioning antennae, the on-board receiver system and communication interface devices, etc (shown in Figure 3). The on-board unit can continuously measure different parameters, tag the data with time and position information, reports irregular conditions.

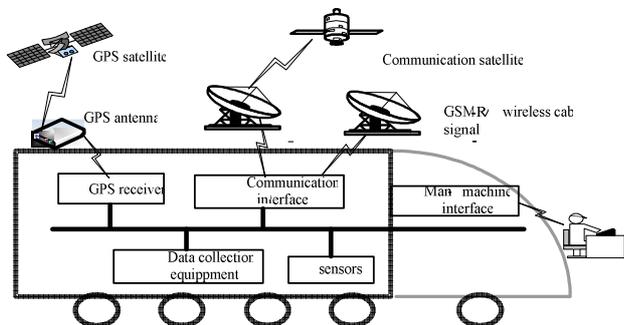


Figure 3. On-board unit design

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.

4.3 Communication Links between On-board Monitors and the Control Centre

The track circuit train control system will not be available to transmit information from trackside to on-board units in Qinghai-Tibet line mainly due to the bad environment along the line. There are two solutions under research. One is an intermittent radio based on cab signal system (Wang, et al., 2002; Ma et al., 2002). Instead of track circuit, an intermittent radio link between the on-board units and the station is used to transmit and receive the train control information within a radius of 3km from the station. The control centre is connected with the station by the optical fibre network. The other is real-time, continuous communication between the on-board units and the control centre. Until now, the specialists of China' Ministry of Railways are inclined to choose the second solution. So the paper focuses on the latter. Communication Links between on-board monitors and the control centre of the latter are shown in figure 4.

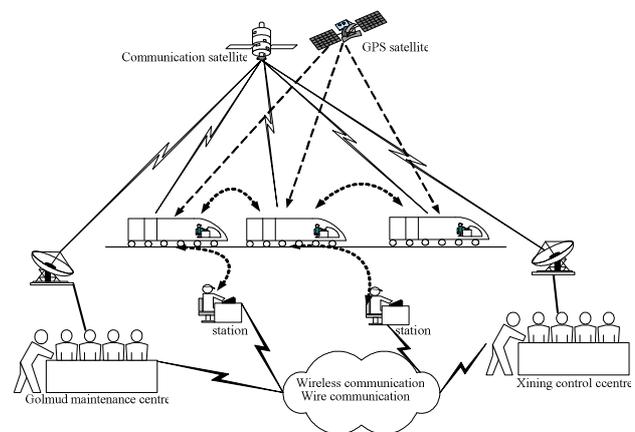


Figure 4. Communication link architecture

5. CONCLUSIONS

China' Ministry of Railways has produced a series of projects and operating solutions to simplify the organisation of rail traffic in highly mountainous areas. Even though the Golmud-Lhasa section of the Qinghai-Tibet main line will not be handling very substantial quantities of freight, it has been decided that the track foundations should be built to Class I standard for state railways. In addition, China' Ministry of Railways will greatly improve operation management of Qinghai-Tibet line after completion, as well as ensure the project quality during construction. The aims of QTIMP are oriented toward the latter. It provides the guidelines for the information management of the Qinghai-Tibet railroad.

In this paper, we briefly introduces Qinghai-Tibet Railway project, emphasizes the need of QTIMP in section one. Section two gives an overview of the G3 technique integration. Section three describes the architecture of QTIMP. Section four primarily deals with the applications of G3 technique integration to QTIMP. Generally, the railway process is based on different tasks, which need different software tools to be performed. These tools generally have to work on the same data. Therefore, QTIMP must be designed according to the modular system, each system will be integrated with the existing systems and further develop into a real multipurpose management system. Currently many systems have been developed, which play an important role in the transport process, marketing and management. It is necessary to be compatible with these developed systems.

Qinghai-Tibet railway. Journal of the China Railway Society. 24(3), pp. 112-117.

ACKNOWLEDGEMENTS

The Qinghai-Tibet Railway information management planning is the result of a project funded by the command headquarters of the Qinghai-Tibet Railway.

REFERENCE

Chakrabarti, S., Mishra, A., 1999. A network architecture for global wireless position location services. IEEE International Conference on Communications, Vol. 3, pp. 6-10.

Derekenaris, G., Garofalakis, J., Makris, C., Prentzas, J., Sioutas, S., Tsakalidis, A., 2001. Integrating GIS, GPS and GSM technologies for the effective management of ambulances. Computers, Environment and Urban Systems. 25(3), pp. 267-278.

Lin, C.E., Li, C.C., Hou, A.S., Wu, C.C., 2002. A real time remote control architecture using mobile communication. Instrumentation and Measurement Technology Conference, Vol. 2, pp. 901-906.

Lu, X.R., Wang, Q.R., Gao, P.P., 2003. Operation and maintenance modes of Qinghai-Tibet railway. Journal of Southwest Jiaotong University. 38(1), pp. 60 .

Ma, J.H., Zhang, Z.Y., Ren, Y., Sun, M.C., 2002. Safety application on radio frequency identification and communication based train control system in Qinghai-Tibet railway. Progress in Safety Science and Technology, Part A, vol. 3, pp. 772-777.

Samaha, J., Kayssi, A., Achkar, R., Azar, M., 2000. G3 integrated three system Technologies. Computer. 33(10), pp.107-110.

Tao, T. Cai, B.G., 2003. Autonomous Decentralized Systems, 2003. A train control system for low-density lines based on intelligent autonomous decentralized system. International Symposium on Autonomous Decentralized System, pp. 203 – 207.

Tsai, S., 2003. Special features of the new Qinghai-Tibet main railway line construction. Rail International. 34 (3), pp. 12-17.
Wang, J.F., Zhang, Y., Cheng, Y.H., Wang, H.S., 2002. Research on the radio based cab signal system used for