INTEGRATED GIS-GPS SYSTEM FOR RAIL OPERATIONS MANAGEMENT

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ABSTRACT

Traditional methods continue to be used in the matters pertaining to rail operations; rail asset management, rail traffic management and rail timetable scheduling. With the passage of time railways have become a significant source of transportation both in developed and developing countries. Transportation infrastructure is vital for economic and social development of any country. This research clearly elaborates how the existing coordination between the trains and regional rail traffic control units can be improved. The existing coordination between a rail locomotive and the regional Traffic Control Unit (TCU) is mainly through cellular phones in Pakistan. This makes current system prone to large probability for the errors and uncertainty in train location tracking. In the research, the rail position data obtained from GPS module and android applications has been used and tested for schedule optimization. Another major goal of this study is to use the GIS digitized map for rail infrastructure and asset management. The railway track between Rawalpindi and Lalamusa has been digitized using GIS digitization tools thus devising a mechanism for managing railway asset data. Global Positioning System (GPS) and Geographic Information System (GIS) based integrated techniques can increase the efficiency of rail traffic operations appreciably. Lastly, the location data has been used for rail schedule optimization. The application of such modern techniques will help in faster decision making, improved coordination, and safer and smoother rail operations.

Keywords: Traffic Control Unit, Geographic Information System, Global Positioning System, rail operations, asset management, schedule optimization.

1. STUDY BACKGROUND

Transportation infrastructure involves one of the largest investments by any country and plays an important role in the economic and social development of the state. Movement of people and goods is vital to every aspect of the country's economy and without a properly established transport system; a country cannot develop in pace to the modern world. Multimodel transportation systems are an integral part of urbanized culture. With the passage of time railways have become a major source of transportation both in developed and developing countries.

In Pakistan, the road network has flourished well in contrast to the railway system which has constantly been in a deteriorating state. The Railways network of Pakistan comprises of 7,791 route-kilometers. The double-track section comprises of 1,043 km, 285 km includes electrified sections and the remaining railway network is single track (JICA, 2006).

The rail sector in Pakistan was much proficient and productive until 1970s. But the governments in Pakistan have not paid adequate attention to the growth and maintenance of this major mode of transportation. Train delays, lower train speed and poor service conditions have forced people to shift to road transport, thus creating an immense passenger load on highways and motorways of the country.

Pakistan Railways has a very limited capacity to fulfil the ever increasing travel demands. Moreover, under prevailing conditions of corruption, mismanagement and lack of technological expertise, existing

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capability of rail systems cannot be fully utilized. It is difficult and burdensome to manage such a complex system manually. Thus it is essential that modern methods are employed to manage this system much more precisely and efficiently in order to avoid delays, accidents and safety concerns.

Global Positioning System (GPS) and Geographic Information System (GIS) based asset management technique for railways can significantly increase the efficiency of traffic operations. It can make noteworthy contributions to safety, including responses to natural and man-made disasters. This is why many railroad systems in the modern world have employed GIS software in order to manage complex rail systems much more efficiently.

Digitization of the railway network and use of GPS for location tracking will support railway transport organization, passenger & freight transport, marketing services and will help flourish other associated businesses. It will help devise a mechanism for the visual display of the schedules for passenger and freight transportation. Pakistan Railways' existing network map has been shown below.

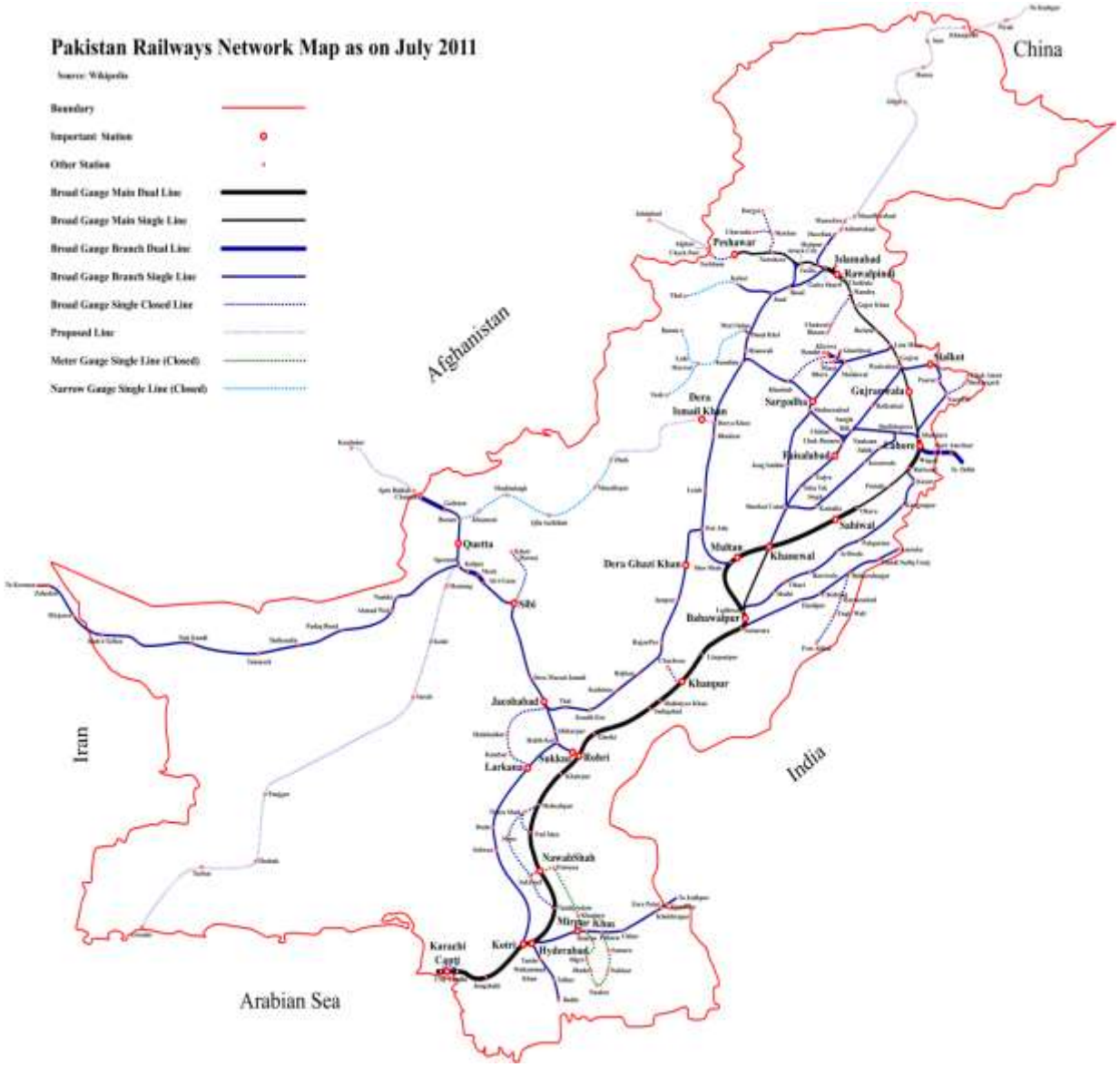

Figure1.1: Pakistan Railways (PR) Network

2. PROBLEM STATEMENT

In Pakistan, manual system is used to locate the position of trains. The person on duty as a dispatcher manages the traffic system manually. He receives information through phone calls and has to draw the time-distance graph by hand (see diagram on the next page). This process is time consuming, inefficient and is prone to human error; thus resulting in train delays.

Figure 2.1: A Dispatcher Working at a Traffic Control Center in Pakistan

The main safety issues are in the form of accidents and most of the accidents are related to signaling and infrastructure. The human involvement at control centers lead to accidents due to human error, carelessness or negligence. This problem can be addressed by developing an automated system that will form a communication channel between the train driver and the control center. By means of this, the control center will be able to detect the train's location and speed to recognize possible safety dangers; such as collision areas, over speeding and disobedience to signals. With accurate knowledge of train position, the control center can also alert the train drivers of the possible security threats and points of conflict in advance. This will make the drivers to avoid or at least reduce the delays and harmful consequences.

The digitization of the railway track using GIS technology and the use of GPS system to locate the position of trains can be an effective solution for resolving problems in the current Pakistani railway system. In many areas of the world, new software and technologies like GPS and GIS etc. are implemented to ensure the transportation systems more reliable, trustworthy and accurate by the elimination of human error factor. On the other hand, Pakistan Railway employees are disinclined towards new technologies and so there is an essential need from the organizational part to take some steps to overcome the current situation of railways.

3. PREVIOUS RESEARCH

In many cases, initial land surveys (conducted for the construction or addition of new rail facilities) need to be updated because of many reasons. This may be either because the previous surveys were conducted a long time ago. In such cases the topography of the earth surface is found to be altered; particularly due to human interference or environmental degradation. As a result, field investigation of railway line need to be carried-out again. This requires greater efforts, technical expertise, time and money.

The use of geographic information data (as stored on computers) comes handy in case of conducting feasibility studies of previous models. For example, there have been many studies carried-out in Pakistan for Karachi Circular Railway (KCR) up-gradation project (JICA, 2006). The updated survey data can be made available without on ground visits using remote sensing and satellite imageries. GIS provides precise data for the railways designs and reevaluation in such cases. This ultimately helps in better decision making.

Xei Wei (1992) utilized the remote sensing technology and combined it with GIS to develop a system for railways design. The geographic data was drawn in form of satellite imagery from LANDSAT TM and a GIS database was constructed with the useful data. The function of this system was to facilitate the pre-design process of any future railways projects.

Guler, Akad and Ergun (2004) focused their research on Railways Asset management. They collected extensive data ranging from geographical and physical to administrative. This data was used to create a comprehensive GIS that included detailed information about every feature directly or indirectly associated to the Turkish State Railway network. The paper aimed at exhibiting the potential of GIS technology in the management of track assets.

Abid, M. M., & Khan, M. B. (2013) employed varies statistical techniques for optimum rail timetable scheduling and rescheduling in Pakistan. The standard rail program generated which included stations between Rawalpindi and Lalamusa in Pakistan.

The expected benefits of Integrated GIS GPS System include:

- Improved maintenance of rail infrastructure records
- Prevention in fuel and rail infrastructure theft
- Poor infrastructure point alerts
- Handy information of rail infrastructure which would support improved decision making
- Lesser train delays and cancellations
- Accurate information availability for commuters
- Improved overall system performance

4. METHODOLOGY

This study frame work aims to provide a computer aided tool to the train managers in Pakistan so that they can actively track and record the movements of the locomotives which can then help them in the analysis and scheduling of trains. This research also aims to provide a platform for employing latest techniques for the assets management purposes. This System that is proposed is termed as “Integrated GIS-GPS System for Rail Operations Management” which uses GPS as a spatial data source for GIS.

GIS is used for storing transportation data. The geographic data is typically available in such formats that it cannot be directly integrated with other GIS data. To use these types of data in GIS, it is needed to align it with present geographically referenced data; this process is termed as geo-referencing. Geo-referencing is a necessary step in the digitizing process. Digitizing in GIS is the process of "tracing" the information from images and maps in a geographically precise way. The process of geo-referencing depends on the coordination or synchronization of points on the scanned image (data to be geo-referenced) with points on a geographically referenced data (data to which the image will be geo-referenced). By "linking" points on the image with those same locations in the geographically referenced data, a polynomial transformation is formed that converts the location of the entire image to the correct geographic location.

It forms a passive component of the system we have proposed as the actual tracking of the trains can be done without the use of such software. Tracking requires a map layer to work on which can be either interactive or non-interactive. These map layers e.g. Open Streets, are easily available and are being used by popular geographic location software like Google Earth. Tracking can be performed quite efficiently on these platforms.

However, over the duration of this project we have come across many officials of Pakistan Railways who have expressed a burgeoning need of improving the record-keeping and management of railways assets. This led us to include the aspect of Railway Asset Management in the scope of our project and we used GIS as a base technology for this purpose.

Assets management comprises all systems, methods, procedures and tools to optimize costs, performance and risks for the complete rail infrastructure life cycle. The aim is to realize the best 'value for money'. These optimizations shall address all infrastructure activities (building, maintenance and renewal, including machines and materials) over the whole life cycle as well as the consequences of these activities for the government as owner and for the train operators and passengers as users. We, however, intend to provide a basic method to serve the immediate needs of the Pakistan railways with a hope that it would be expanded upon in the future.

5. WORKING MECHANISM

QGIS is a cross-platform Open Source Geographic Information system licensed under the GNU General Public License. This was an ideal choice for us since our aim was to develop the most cost-effective system possible. We digitized certain important features of our chosen track and distributed them in different Shape File layers. These digitized features allow us to store useful information in relevant fields which can be effectively used to manage the railway assets.
Our QGIS Project file consists of the following layers:

- Rail
- Bridges
- Tunnels
- Station Area
- Map Layer (Hybrid, Street or Satellite)

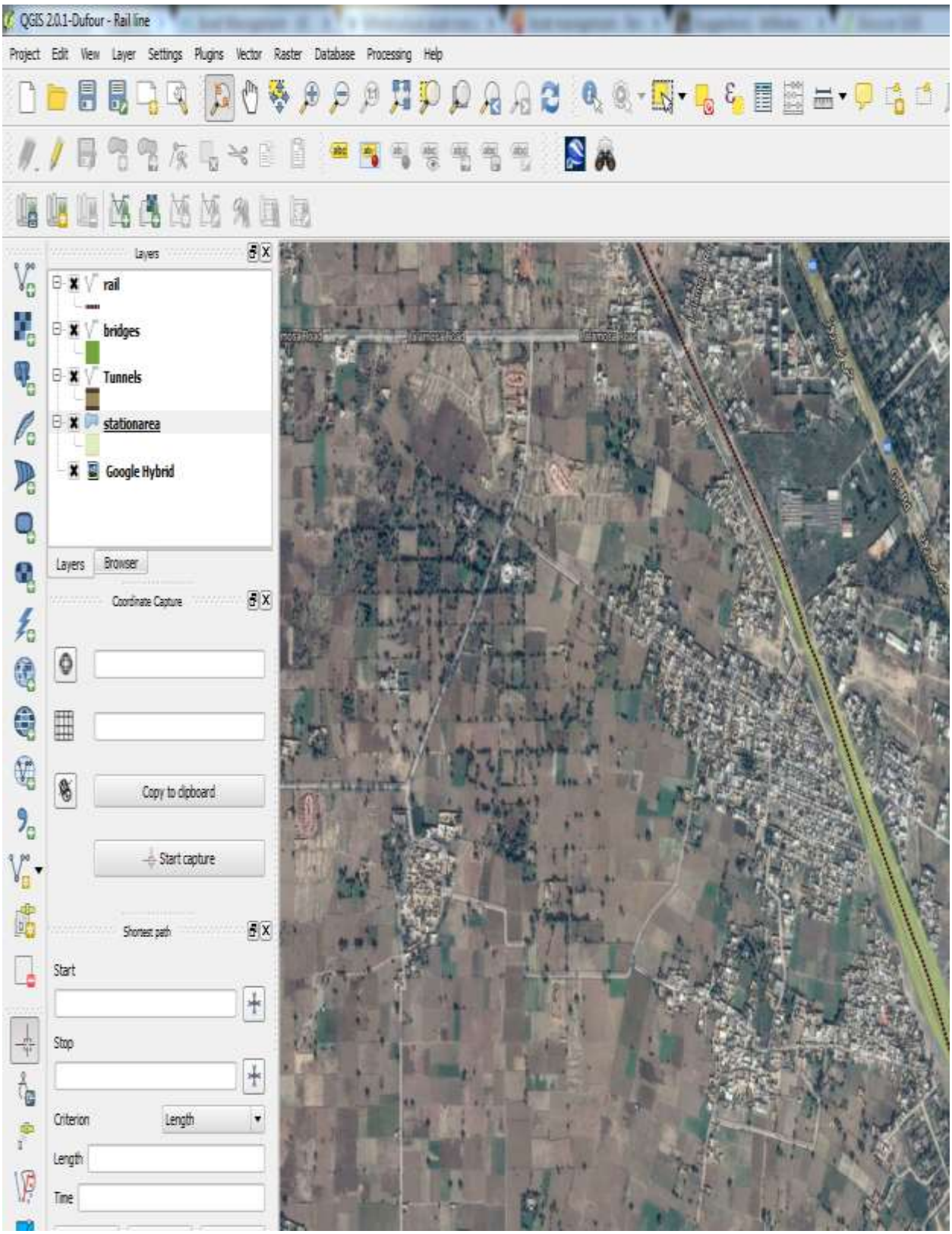

Figure-5.1: Layers Defined in the Project

Each layer consists of carefully geo-referenced features digitized from the satellite imagery underlain below. Also each defined feature in a layer has a set of fields associated with it that can be edited as per the requirement and can be potentially used for management of assets. The fields we included are as follows:

- Name
- Co-ordinates
- Last Maintained
- Maintenance Due Date

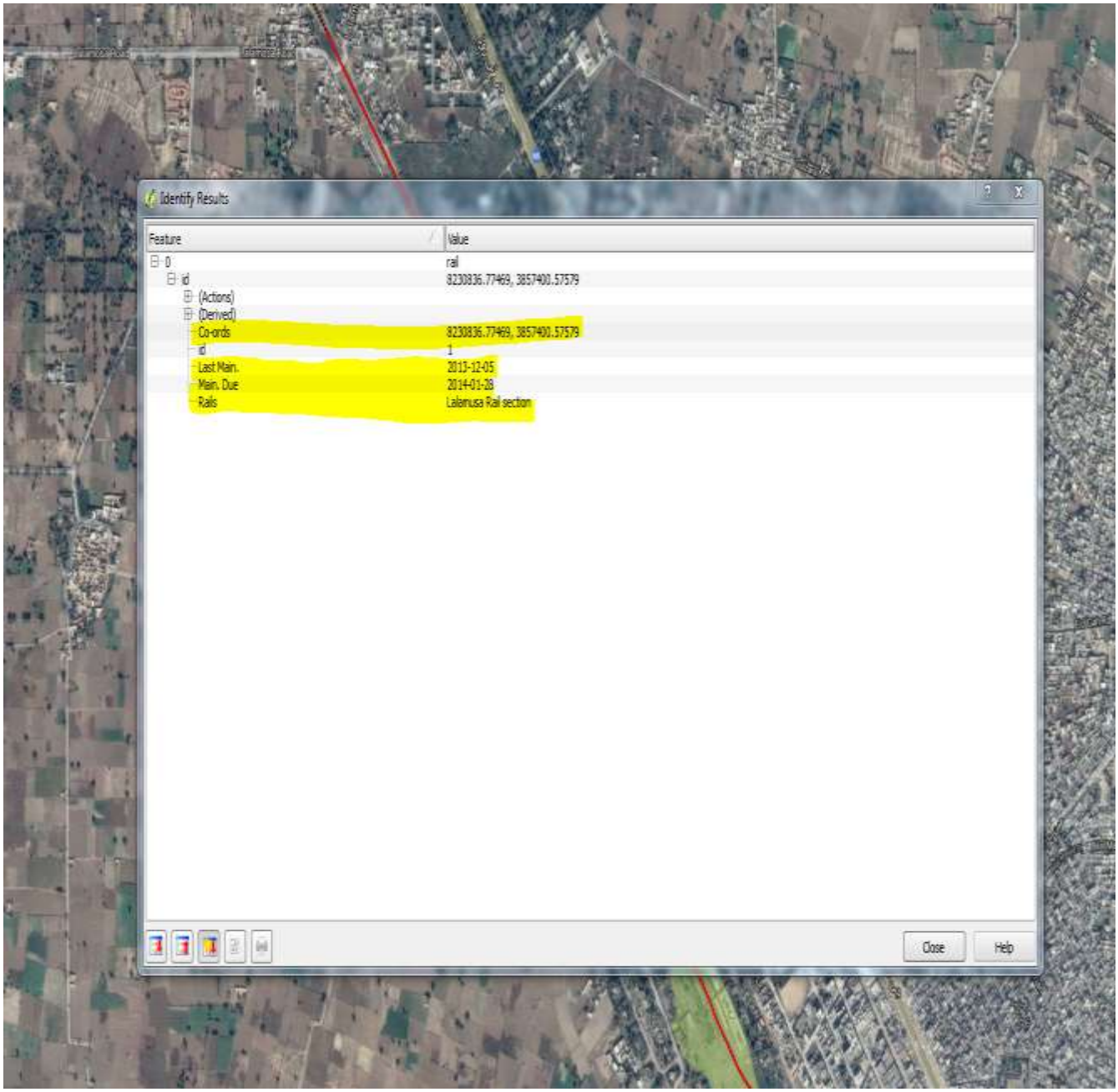

Figure-5.2 Fields of Rail feature

Thus the main functions of GIS are:

- Integration of the spatial data
- Display the attribute data in a user-chosen format
- Make digitized files

GLOBAL POSITIONING SYSTEM (GPS)

GPS is used as a tool for collecting the spatial data. The receiver of the GPS unit recognizes the longitudinal and latitudinal location and speed of a specific train by means of receiving data through GPS satellites. The data of location is sent from time to time to the main server through GSM transmitter of the unit. In case of failure of GSM connectivity, the device can store data in a buffer, and is capable of synchronization when GSM gets back by the distant servers. The devices can also act in reaction to the guidelines and data demands from the remote server according to the needs of railway administration. GSM has been selected as the communication medium among train locator and the central server to improve accessibility of our system as the current GSM network covers almost the entire country.

The most important part was the choice of a GPS device and the medium through which the data is to be transmitted. The device used is an Android (4.0x Jellybean) phone. The android applications GPS Essentials and Real Time GPS Tracker are used.

In order to track the trains in real time it was an absolute necessity that we have an active online server to which the data can be sent continuously and hence, displayed to be made use of by the operator.

ANDROID DEVICES

Almost all the Android Smart phones today have an in-built GPS support and the wide variety of relevant apps available for our purpose made these devices an obvious choice for us. However, the apps that were most compatible in carrying out this research were:

- GPS Essentials by Michael Scholl Meyer
- Real Time GPS Tracker by Green Alp

The data is saved by the app and can be exported in KML, GPX and KMZ formats which can then be imported and / or overlaid on several GIS software.

6. SCHEDULING

Time table Scheduling is a design activity, requiring considerable skill, knowledge and experience to achieve efficient and effective plans to run a transport service. Fundamentally, the aim is to plan to move payloads – freight or passenger - between a defined set of locations at a given speed and business value.

In modern times, computers have been able to eliminate repetitive and manual tasks in the scheduling process and introduced some protection from errors and inconsistencies. It is feasible to construct time tables and schedules entirely by computer but only for very well-understood and straightforward requirements, and certainly not for a transport system as complex as the London Underground. This may change over time, as computers become more capable and as the knowledge and experience of the current tools becomes more widespread.

Time table design relies on fundamental detailed knowledge of the geography of the route or service concerned, the vehicles used and their performance and payload, the demand for the service and how

it is to be managed and operated and engineered. The geographic dimensions of the route and vehicles are measured in time units - how long it takes for particular vehicles to pass from one known location to another in the expected conditions, and especially for railways, how close each vehicle can run behind another, or how close one vehicle can be to another one when meeting at a junction. The designer must know what resources are available for the service – vehicles, routes and termini, energy supplies, environmental and weather considerations, how available the vehicles are for use, where vehicles are stored and maintained, and what maintenance requirements there are. It is also essential to understand the business and customer requirements of the service, and exactly what it has to achieve, connecting with other transport modes, levels of comfort and crowding and the extent to which business and regulatory rules constraint the operations.

The designer and/or computer must know in detail the information outlined above and how each feature depends on the others, and how these vary through days and seasons. Knowledge of practical aspects of the business, its technology, services and routes is essential. Individual, seemingly small constraints such as platform and siding lengths, hard to quantify in algorithms, can influence significantly the approach and eventual solution for any particular timetable. Many elements of designer knowledge can only be developed effectively by site visits and close relationships with operational end users and assets providers, and by observation of actual operations over time.

The timetable design process begins with specification, and gathering of all the essential information that the designer needs. There must also be consideration of the staffing required for the service – a closely-related matter which also requires careful design and whose effectiveness is substantially dependent on the prior creation of a very effective timetable.

A crucial element of the timetable creation process is systematic checking and testing of the design and outputs, which enables the designer not only to achieve the required freedom from defects, but also to detect opportunities for refining the solution and maximizing the potential for the timetable to operate reliably. The checking and testing activities can sometimes be a significant proportion of the overall design effort.

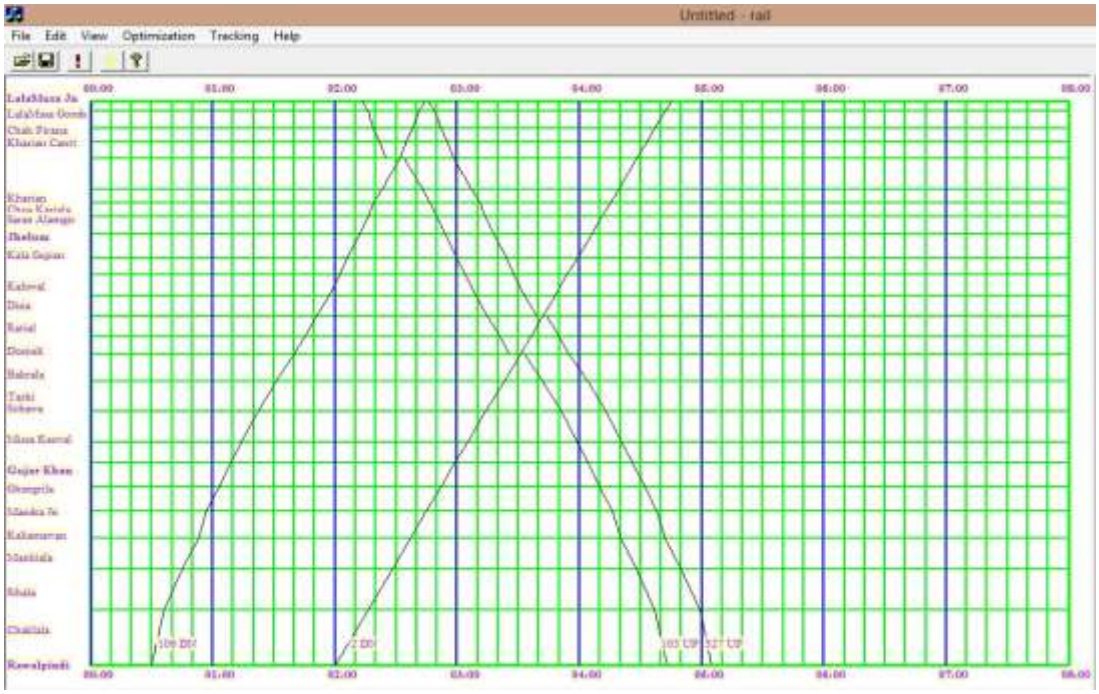

Figure-6.1 Master Graph-Original Schedule of 4 Trains (RWP-LLM) on Rail 7.0

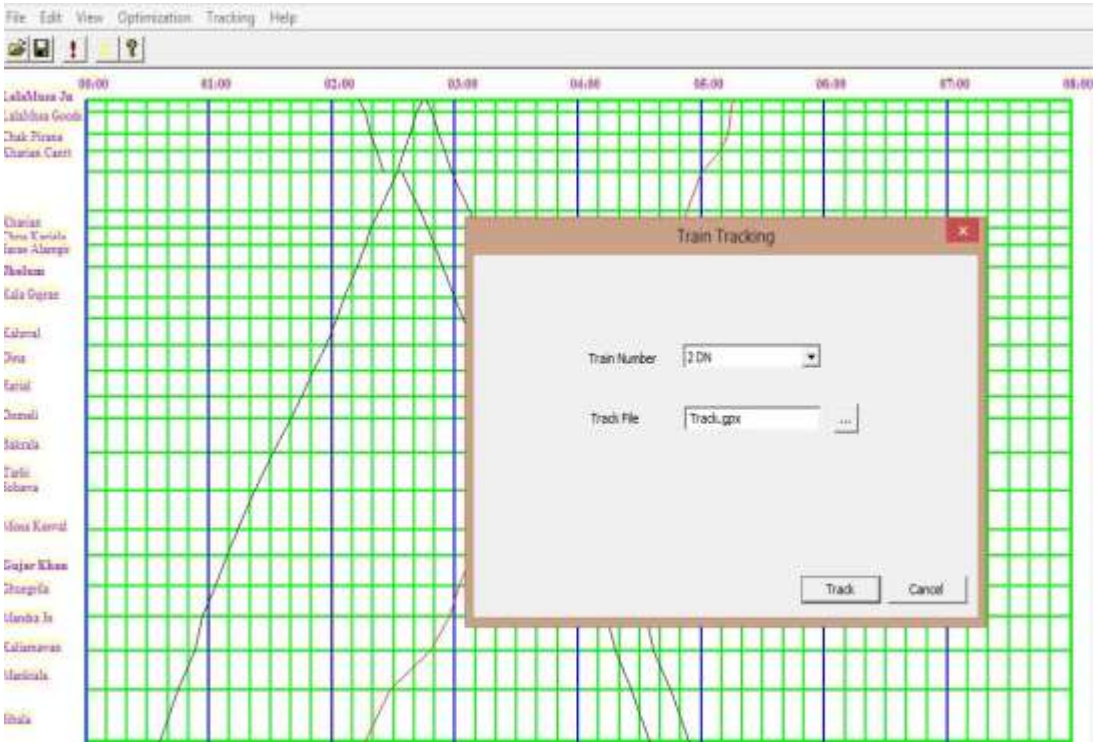

Figure-6.2 Importing the .gpx File into Rail 7.0 Program

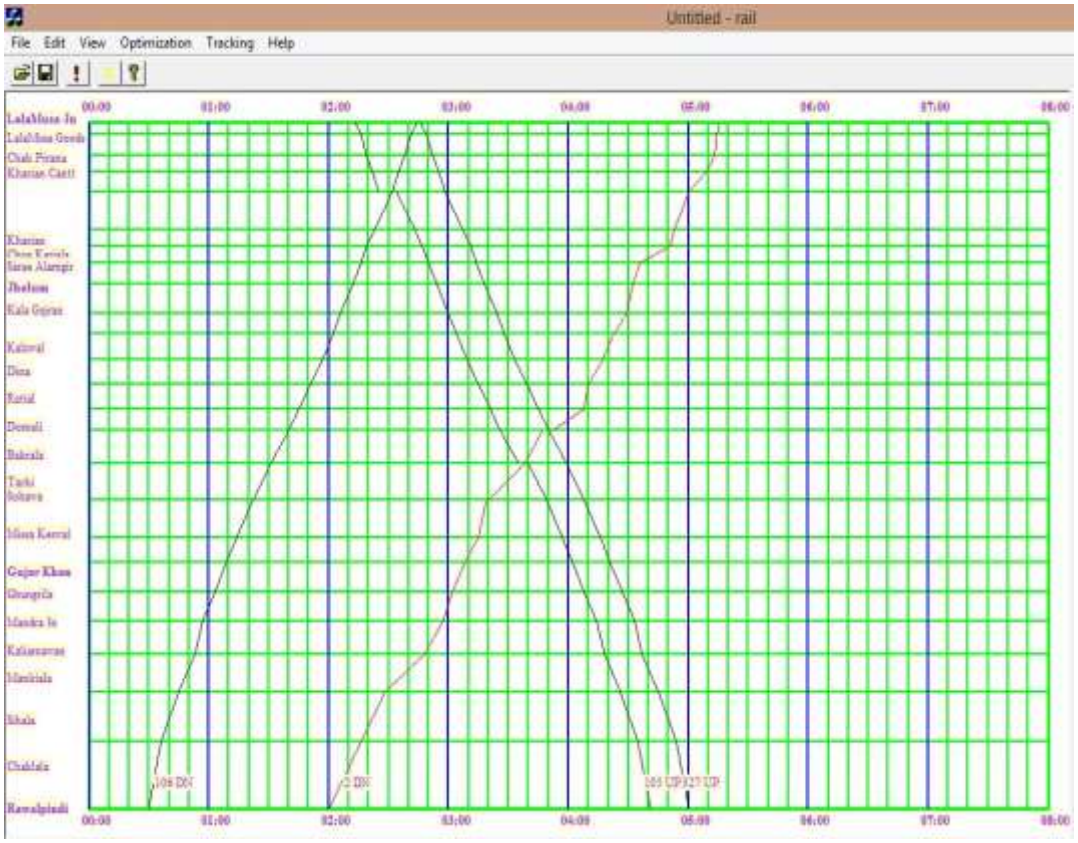

Figure-6.3 Optimized Track Schedule (Note 2DN Train)

At the end of the timetable design process there are multiple outputs to be created, not only the printed timetables for the human reader but also the computer data needed to develop the staff work rosters to operate the service and the data needed to arrange the supply of energy, operation of signals and controls, and to provide online public information.

7. CONCLUSION AND RECOMMENDATIONS

1. It is highly recommended that the proposed system may be employed by the Pakistan Railways.

2. PR needs to employ modern GIS techniques in order to maintain its land records, maintenance schedules and railway asset details.

3. The rail timetable scheduling should be done using modern software in order to ensure robust timetabling. One such technique has been shown in this paper.

4. There is a huge potential for modern research on this topic. Modern researchers need to target the areas of railways scheduling and delay minimization.

5. There is no academia and industrial linkage for Railways in Pakistan. The future researchers and industry experts need to create a forum where the issues pertaining to rail operations are discussed.

6. It is expected that higher cooperation will be provided by Pakistan Railways and Pakistani Universities in this regard.

8. ACKNOWLEDGEMENTS

We are greatly thankful to Assistant Professor Dr. Muhammad Babar Khan, PhD for his invaluable assistance and guidance in carrying out this research.

The authors acknowledge Pakistan Railways (PR), Pakistan Railway Advisory and Consulting Services (PRACS), Railway Carriage Factory Islamabad, Institute of Geographic Information System (IGIS-NUST), School of Electrical Engineering &Computer Science (SEECS-NUST), and NUST Institute of Civil Engineering (NICE-NUST) for providing support and the facilities while carrying out this research.

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